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Ström

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(54) **WEIGHT BASED IMAGE PROCESSING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 41 days.

This patent is subject to a terminal disclaimer.

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(65) **Prior Publication Data**

US 2013/0287295 A1 Oct. 31, 2013

Related U.S. Application Data

(63) Continuation of application No. 11/915,669, filed as application No. PCT/SE2006/000613 on May 24, 2006, now Pat. No. 8,457,417.

(30) **Foreign Application Priority Data**

May 27, 2005 (SE) 0501260.4
Jul. 1, 2005 (WO) PCT/SE2005/001070

(51) **Int. Cl.**
G06T 9/00 (2006.01)
H04N 19/176 (2014.01)
H04N 19/186 (2014.01)

(52) **U.S. Cl.**
CPC ***G06T 9/00*** (2013.01); ***H04N 19/176*** (2014.11); ***H04N 19/186*** (2014.11); *G06T 9/001* (2013.01)

(58) **Field of Classification Search**
USPC 382/162, 166, 232, 234, 235, 239; 341/51, 55; 348/234, 253; 375/E7.084, 375/E7.129, E7.137, E7.166
See application file for complete search history.

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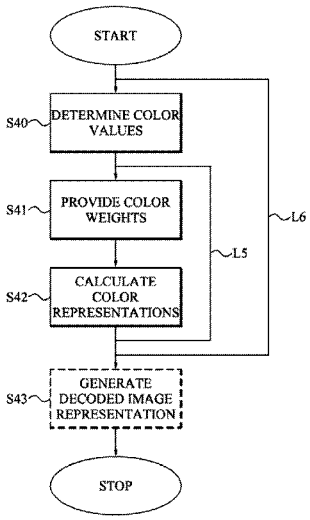
Primary Examiner — Anh Do

(57) **ABSTRACT**

In an image-encoding scheme, an input image is decomposed into several image blocks comprising multiple image elements. The image blocks are encoded into encoded block representations. In this encoding, color weights are assigned to the image elements in the block based on their relative positions in the block. At least two color codeword are determined, at least partly based on the color weights. These codewords are representations of at least two color values. The original colors of the image elements are represented by color representations derivable from combinations of the at least two color values weighted by the assigned color weights.

12 Claims, 15 Drawing Sheets



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8,144,981	B2 *	3/2012	Pettersson et al.	382/166
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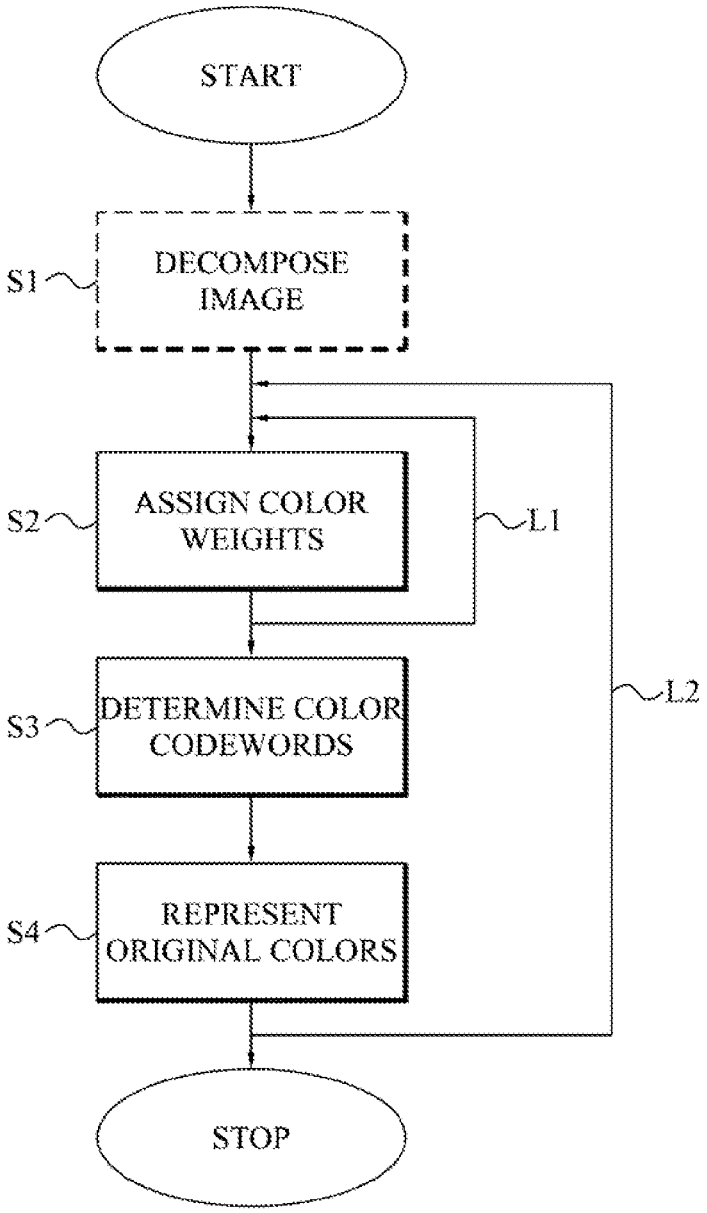
START
S1
DECOMPOSE IMAGE
S2
ASSIGN COLOR WEIGHTS
L1
S3
DETERMINE COLOR CODEWORDS
L2
S4
REPRESENT ORIGINAL COLORS
STOP

Fig. 1

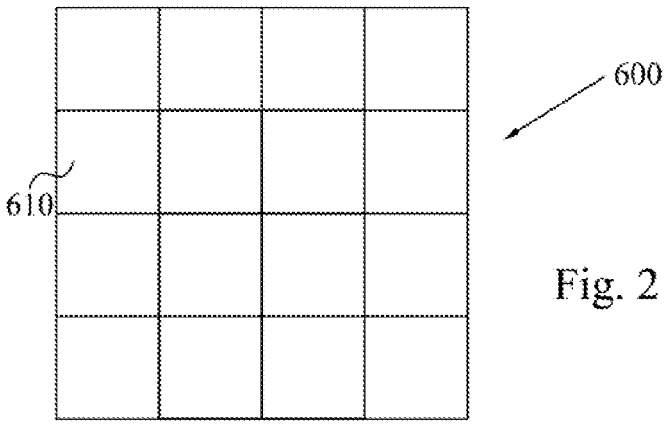
600
610

Fig. 2

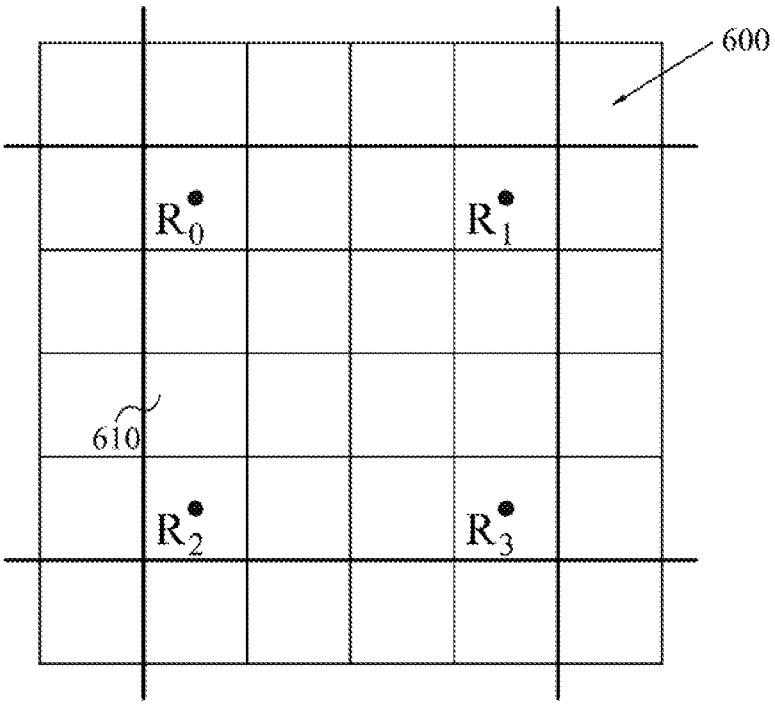

Fig. 3

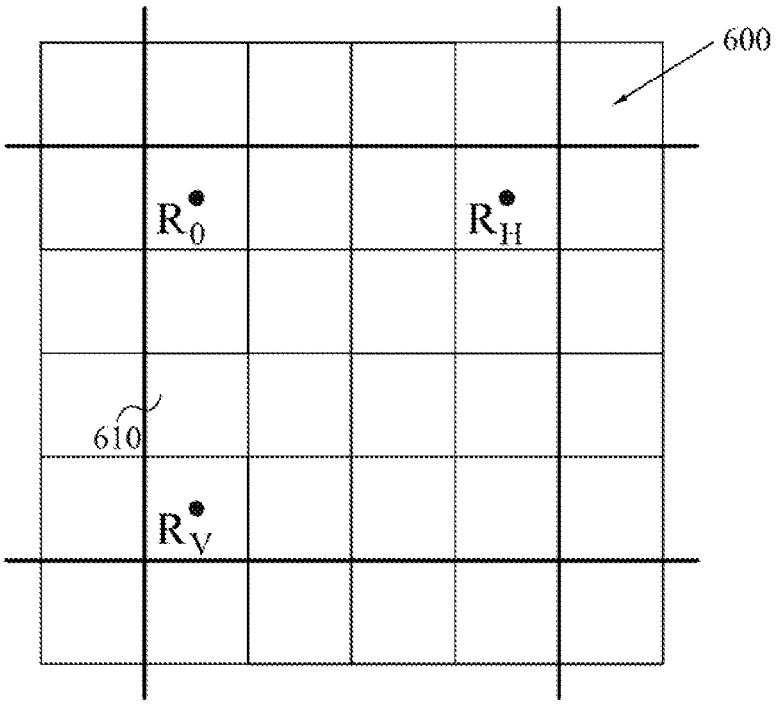

Fig. 5

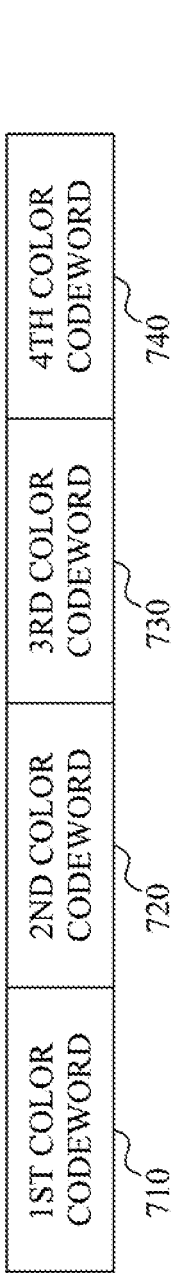
700
1ST COLOR CODEWORD
710
2ND COLOR CODEWORD
720
3RD COLOR CODEWORD
730
4TH COLOR CODEWORD
740

Fig. 4

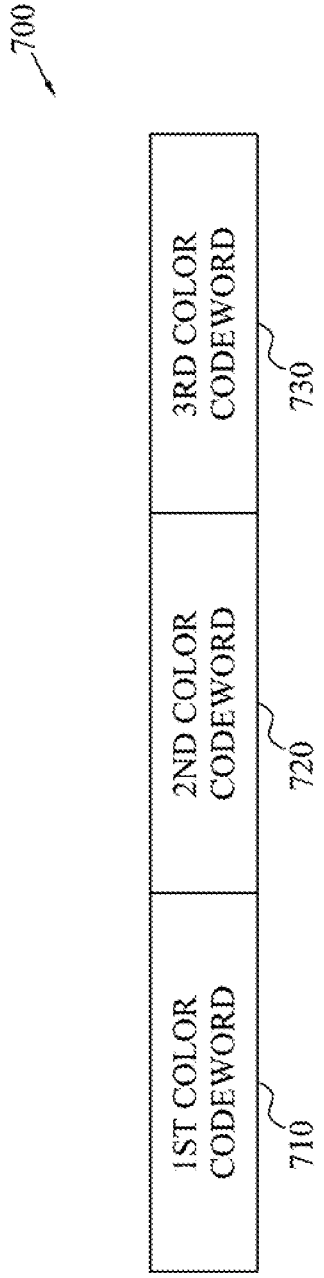
700
1ST COLOR CODEWORD
710
2ND COLOR CODEWORD
720
3RD COLOR CODEWORD
730

Fig. 6

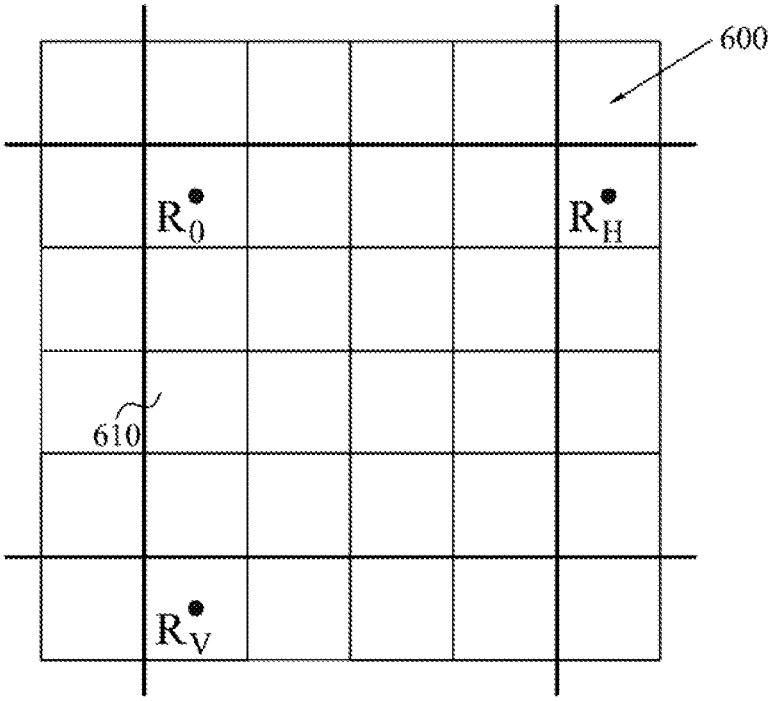

Fig. 7

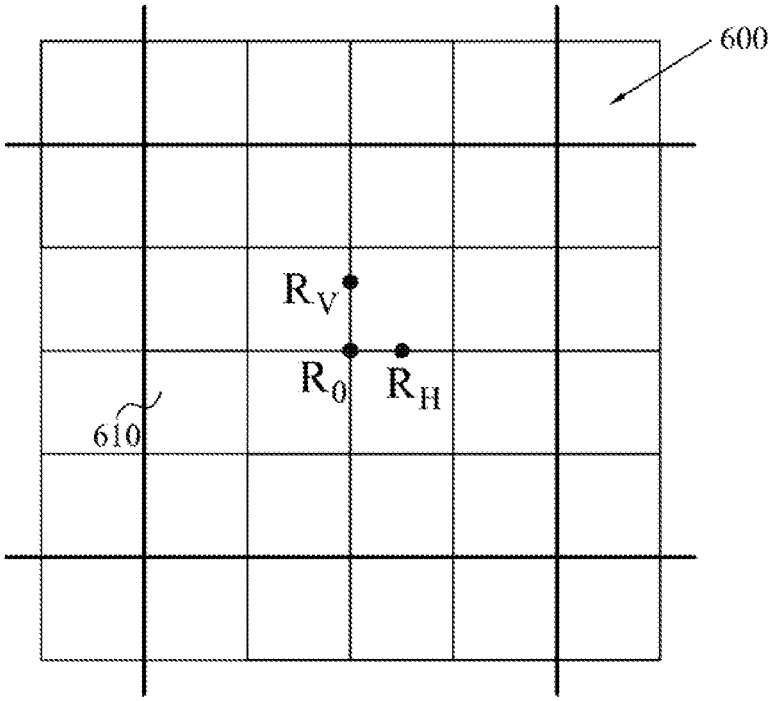

Fig. 8

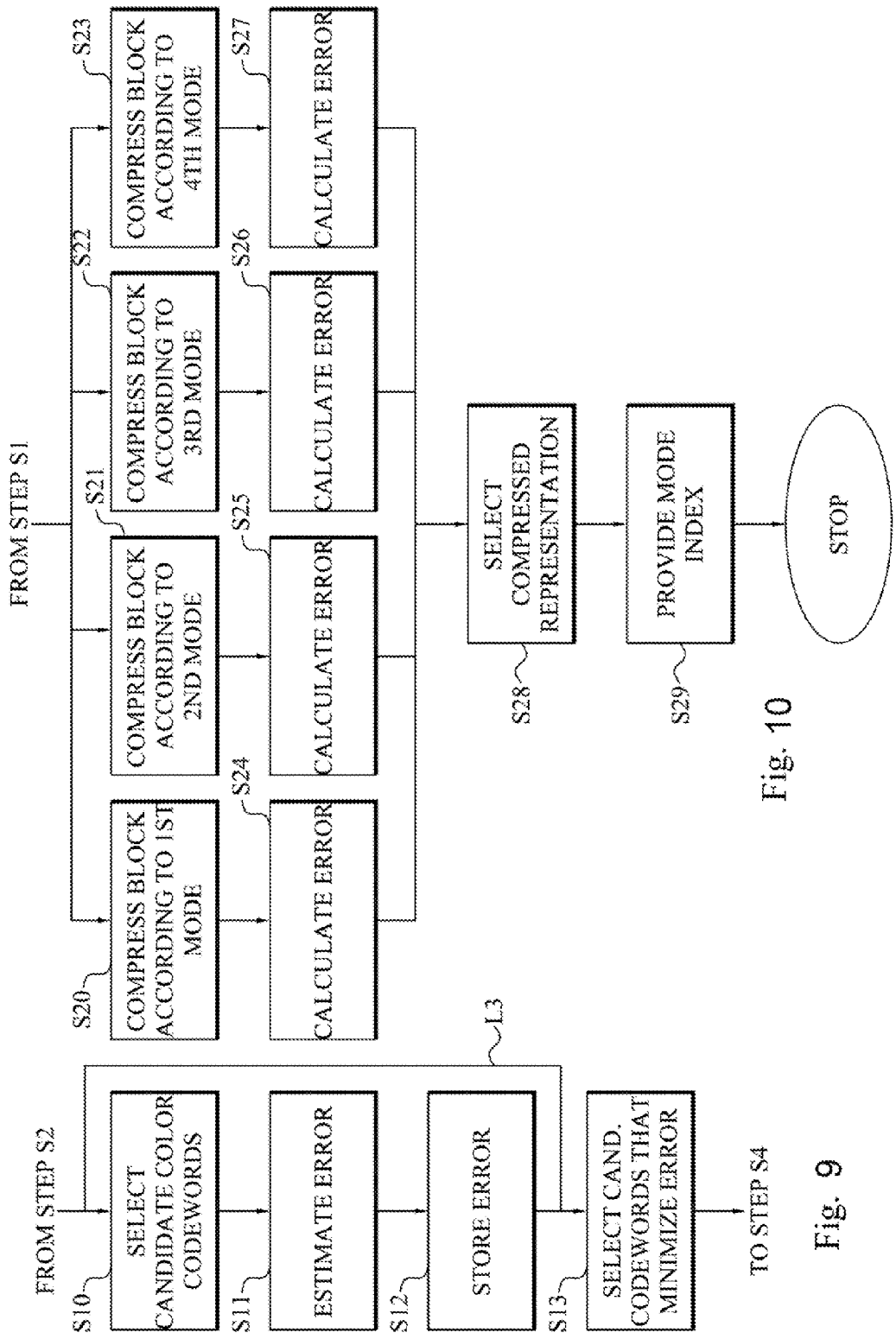
FROM STEP S2
S10
SELECT CANDIDATE COLOR CODEWORDS
S11
ESTIMATE ERROR
S12
STORE ERROR
S13
SELECT CAND. CODEWORDS THAT MINIMIZE ERROR
TO STEP S4
L3
FROM STEP S1
S20
COMPRESS BLOCK ACCORDING TO 1ST MODE
S24
CALCULATE ERROR
S21
COMPRESS BLOCK ACCORDING TO 2ND MODE
S25
CALCULATE ERROR
S22
COMPRESS BLOCK ACCORDING TO 3RD MODE
S26
CALCULATE ERROR
S23
COMPRESS BLOCK ACCORDING TO 4TH MODE
S27
CALCULATE ERROR
S28
SELECT COMPRESSED REPRESENTATION
S29
PROVIDE MODE INDEX
STOP

Fig. 9

Fig. 10

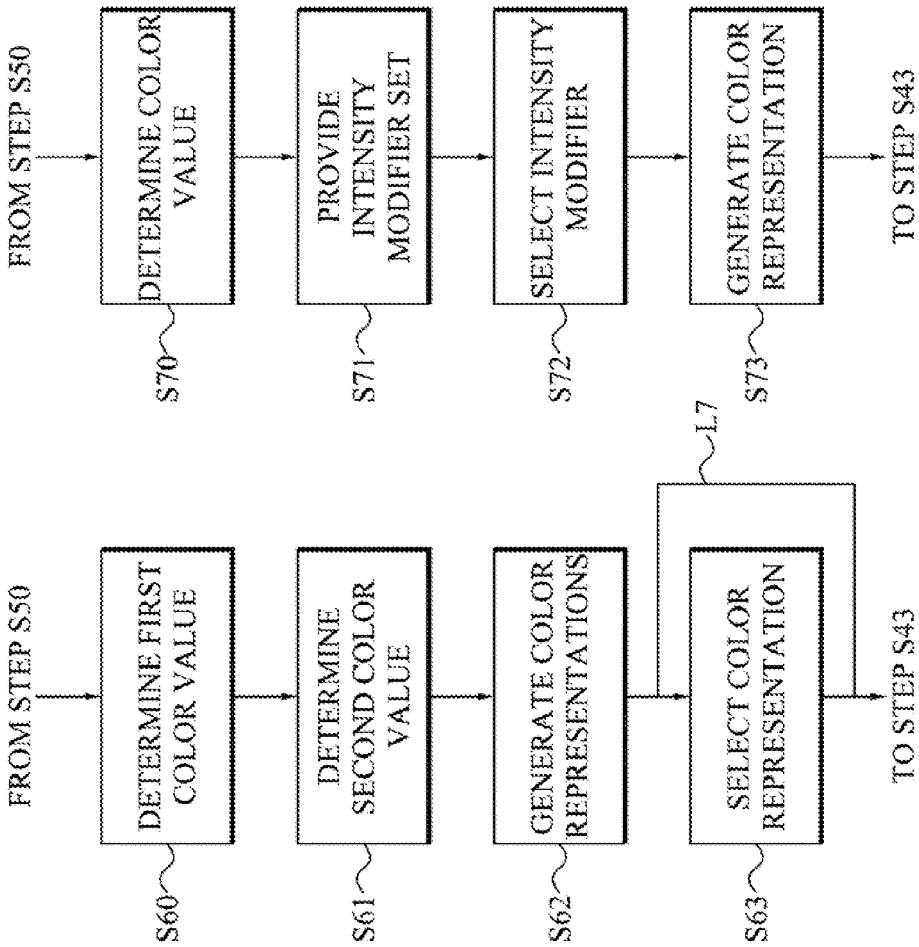

Fig. 21

Fig. 20

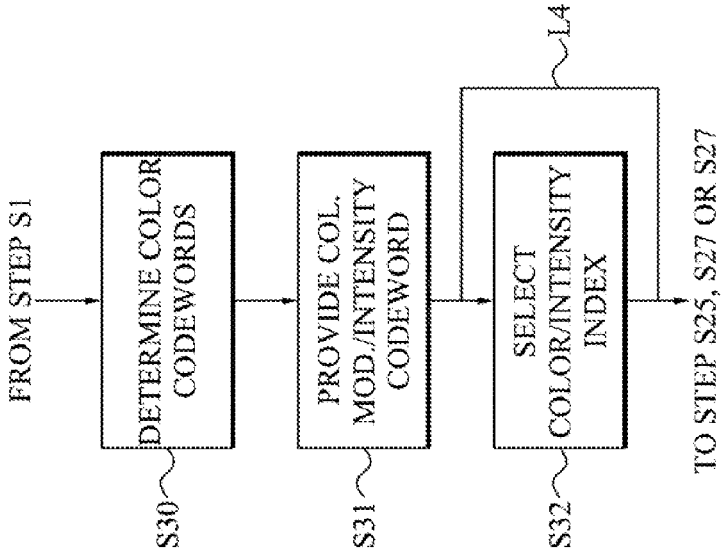

Fig. 11

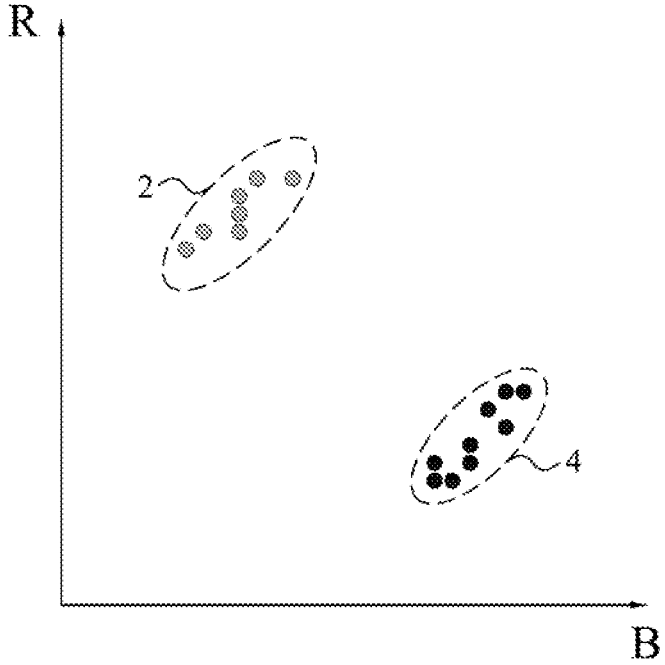

Fig. 12A

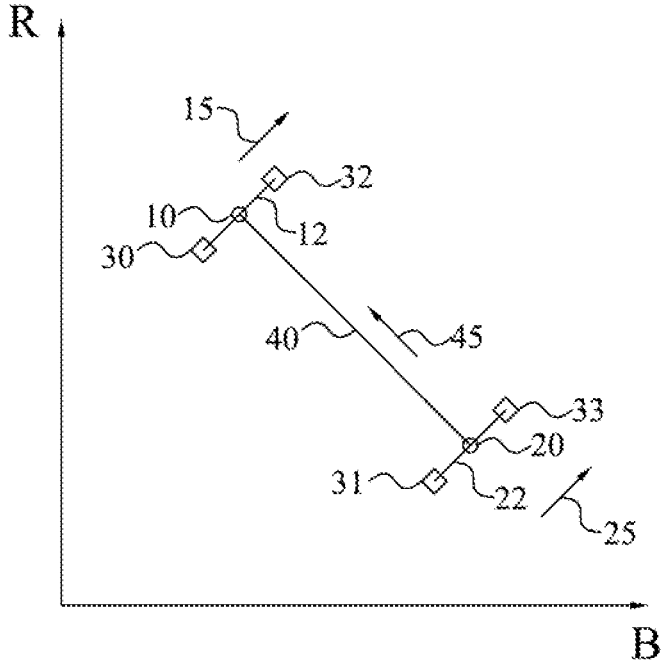

Fig. 12B

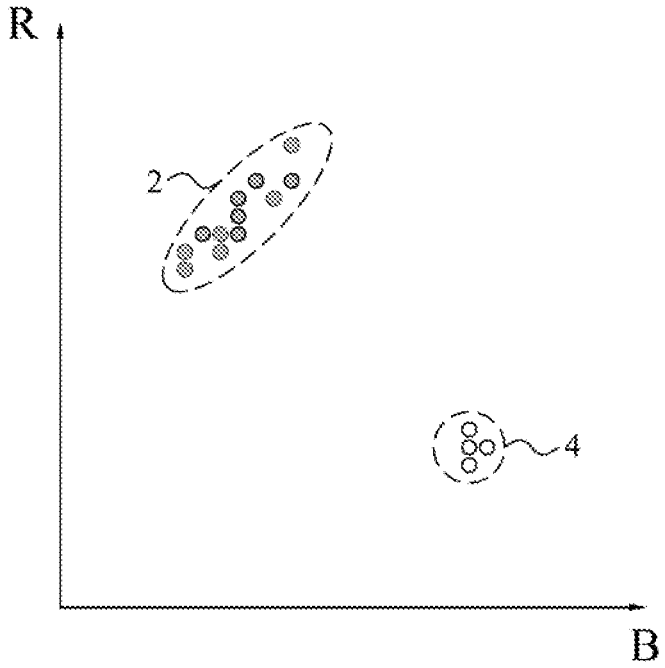

Fig. 13A

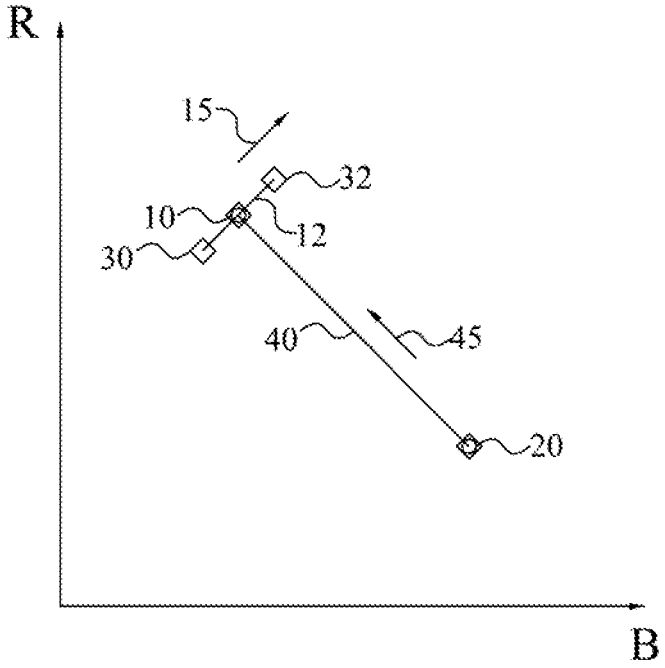

Fig. 13B

Fig. 14

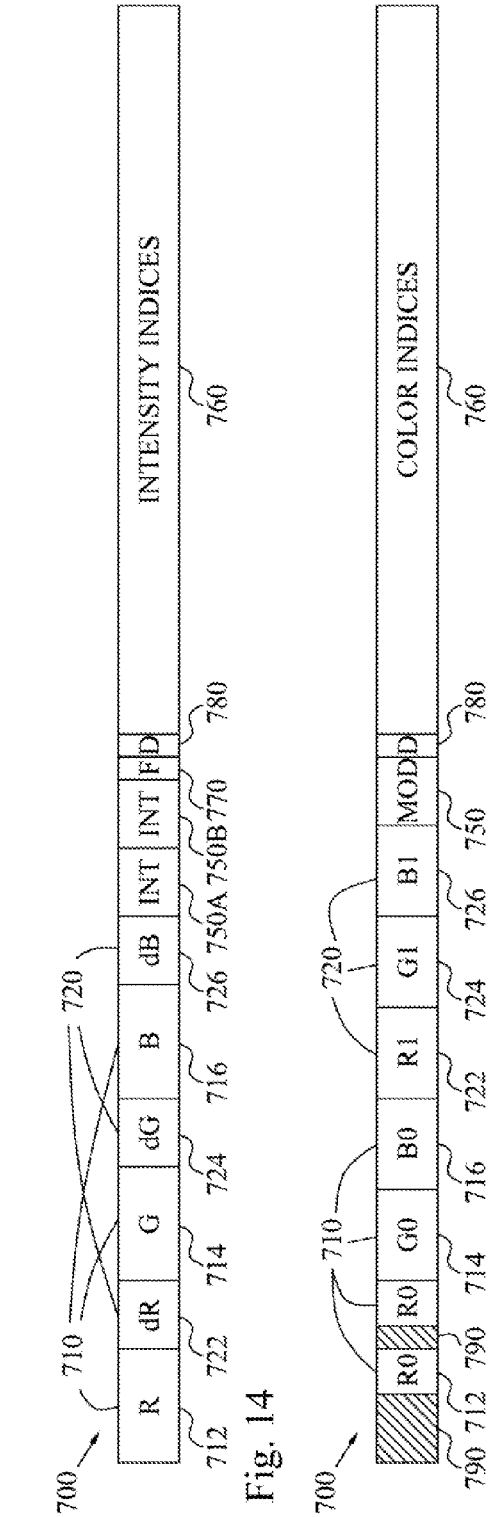

Fig. 15

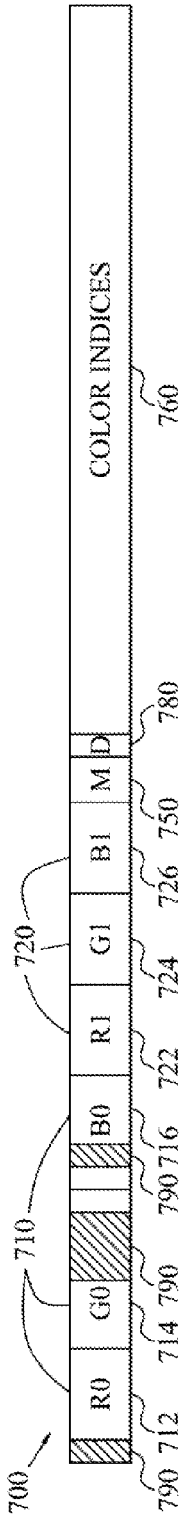

Fig. 16

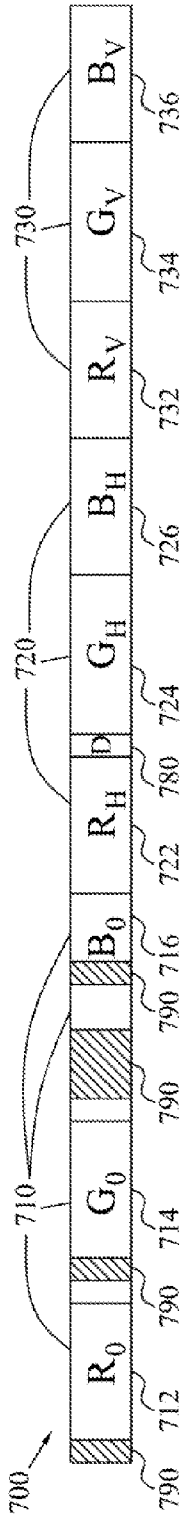

Fig. 17

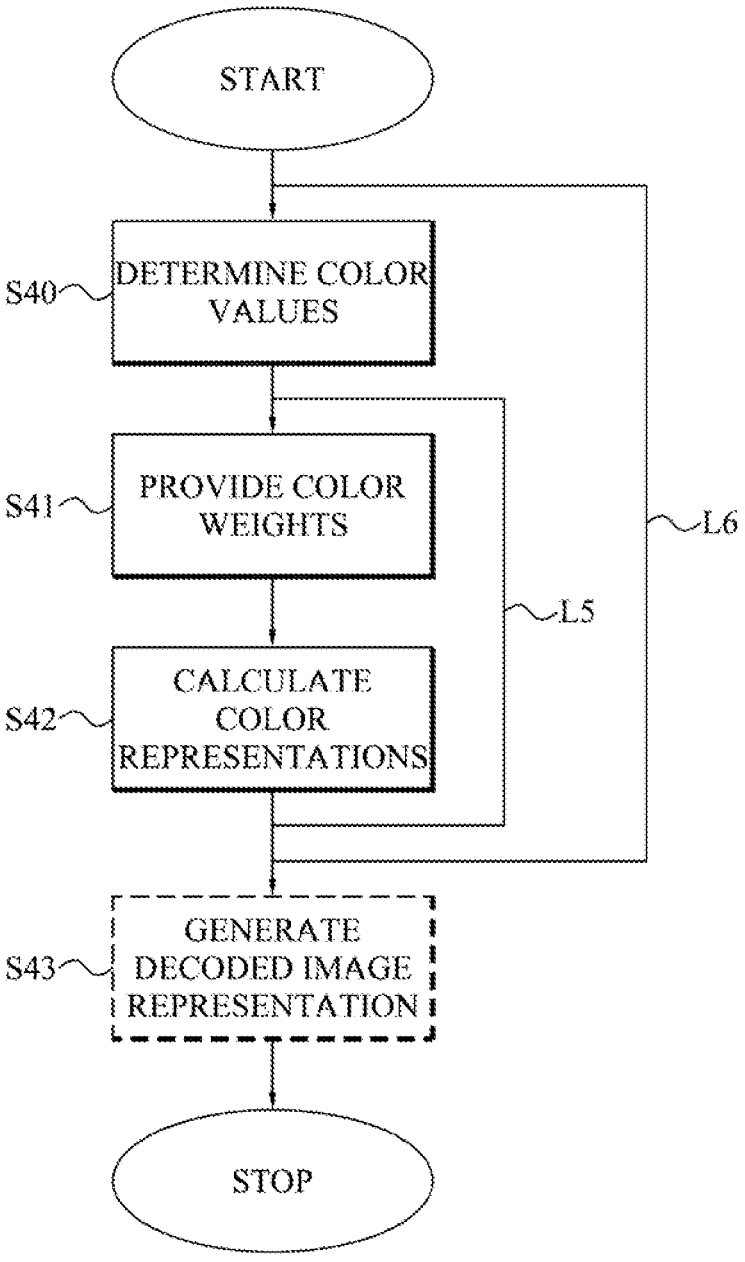
START
S40
DETERMINE COLOR VALUES
S41
PROVIDE COLOR WEIGHTS
S42
CALCULATE COLOR REPRESENTATIONS
S43
GENERATE DECODED IMAGE REPRESENTATION
STOP
L5
L6

Fig. 18

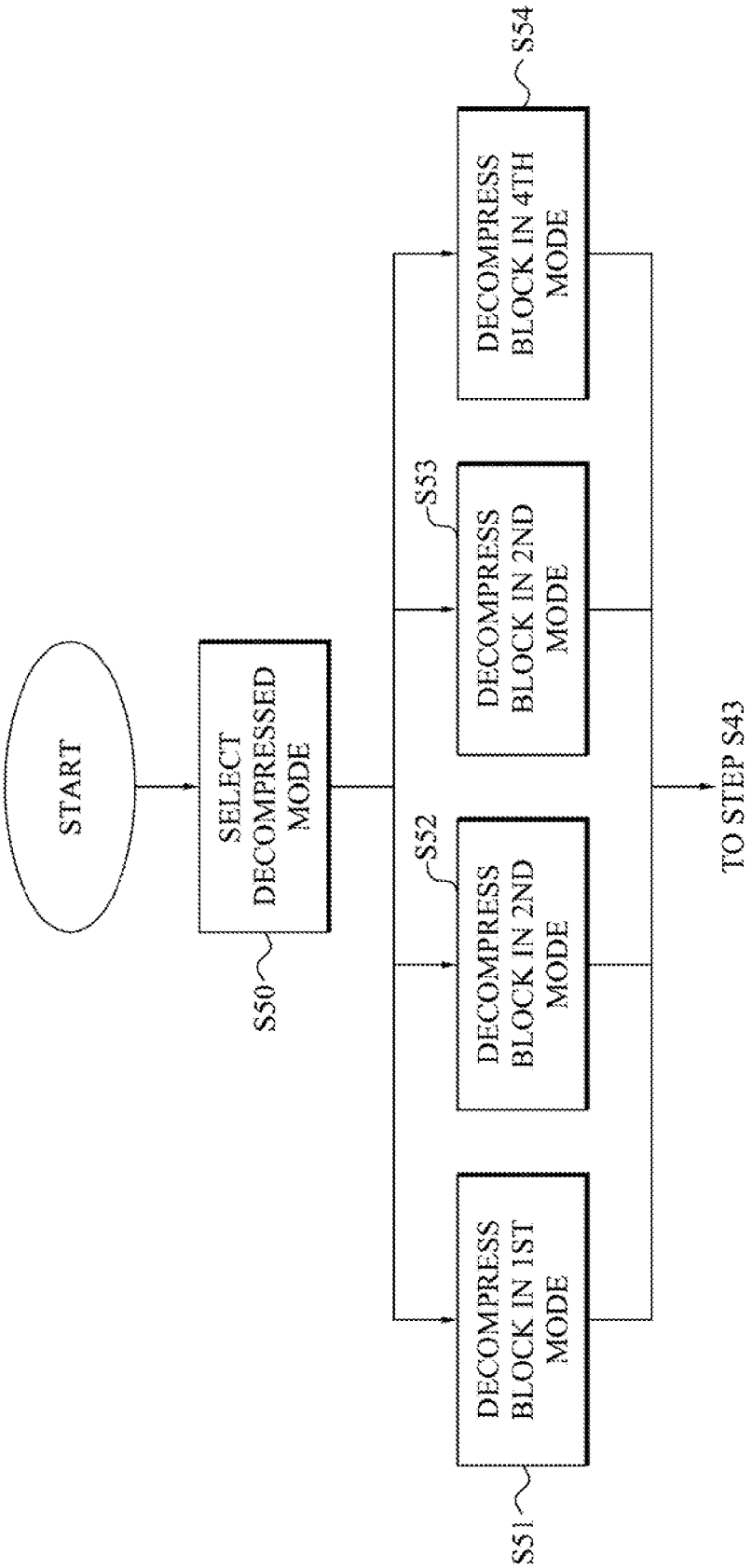
START
SELECT DECOMPRESSED MODE
S50
DECOMPRESS BLOCK IN 1ST MODE
S51
DECOMPRESS BLOCK IN 2ND MODE
S52
DECOMPRESS BLOCK IN 2ND MODE
S53
DECOMPRESS BLOCK IN 4TH MODE
S54
TO STEP S43

Fig. 19

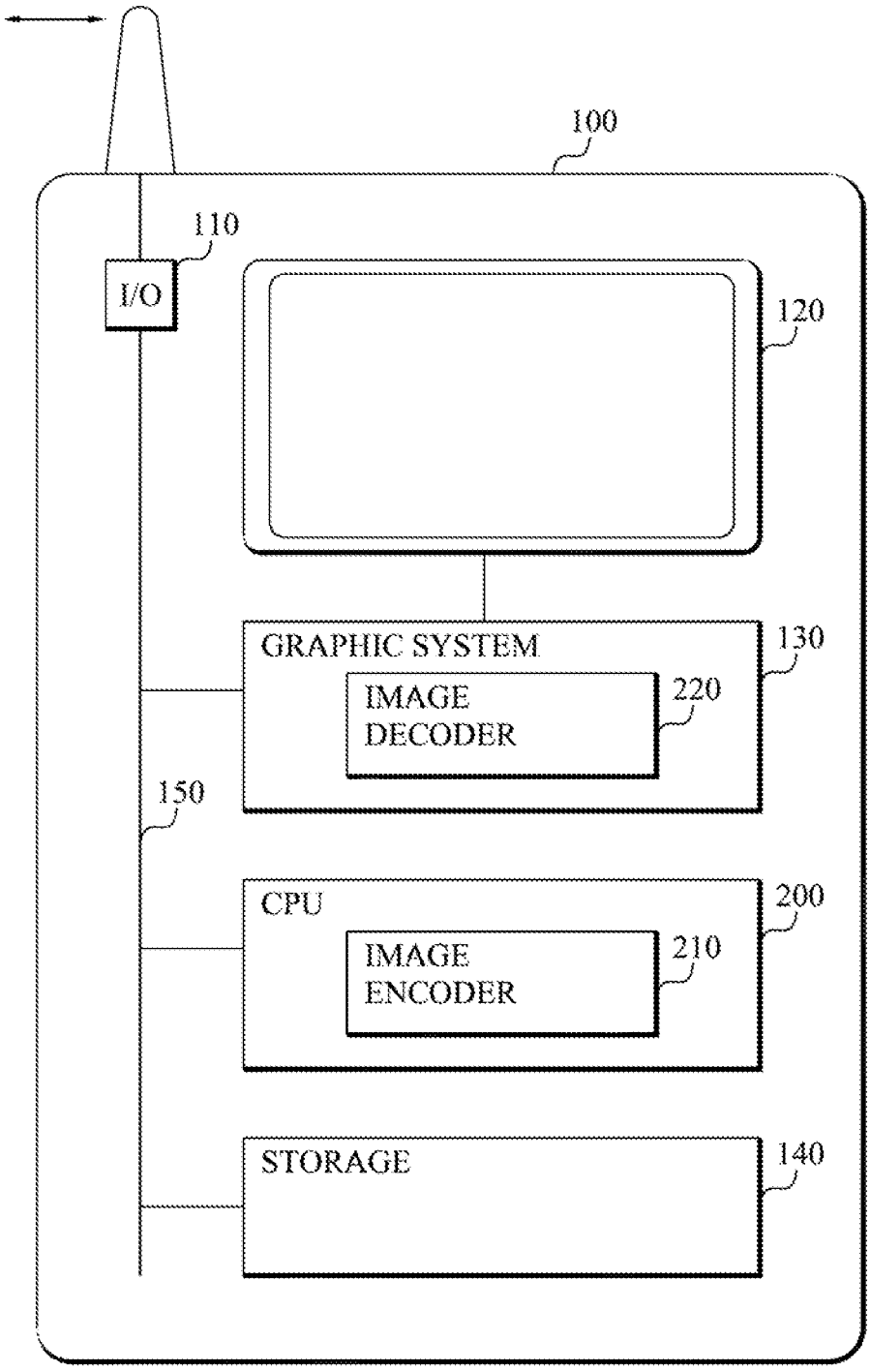
100
110
I/O
120
GRAPHIC SYSTEM
130
IMAGE DECODER
220
150
CPU
200
IMAGE ENCODER
210
STORAGE
140

Fig. 22

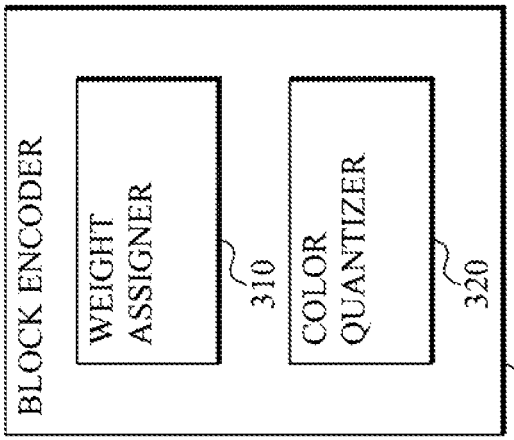
BLOCK ENCODER
WEIGHT ASSIGNER
310
COLOR QUANTIZER
320
300

Fig. 24

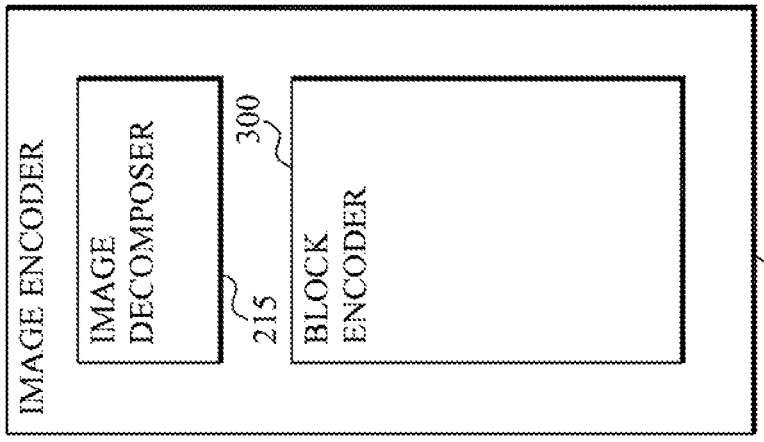
IMAGE ENCODER
IMAGE DECOMPOSER
215
300
BLOCK ENCODER
210

Fig. 23

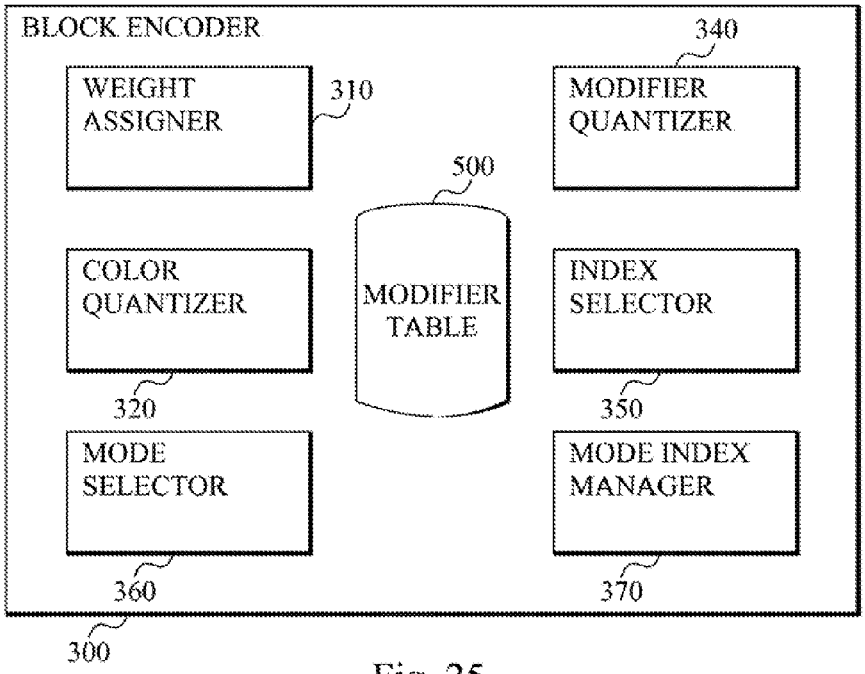
BLOCK ENCODER
WEIGHT ASSIGNER
310
MODIFIER QUANTIZER
340
500
MODIFIER TABLE
COLOR QUANTIZER
320
INDEX SELECTOR
350
MODE SELECTOR
360
MODE INDEX MANAGER
370
300

Fig. 25

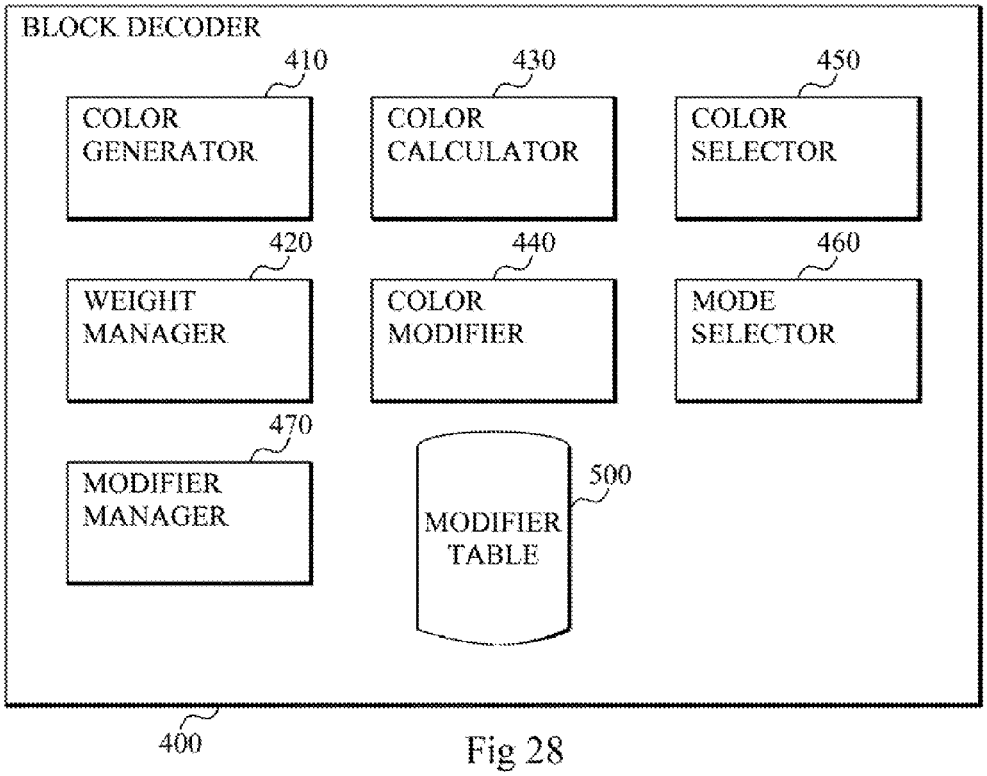
BLOCK DECODER
410
COLOR GENERATOR
430
COLOR CALCULATOR
450
COLOR SELECTOR
420
WEIGHT MANAGER
440
COLOR MODIFIER
460
MODE SELECTOR
470
MODIFIER MANAGER
500
MODIFIER TABLE
400

Fig 28

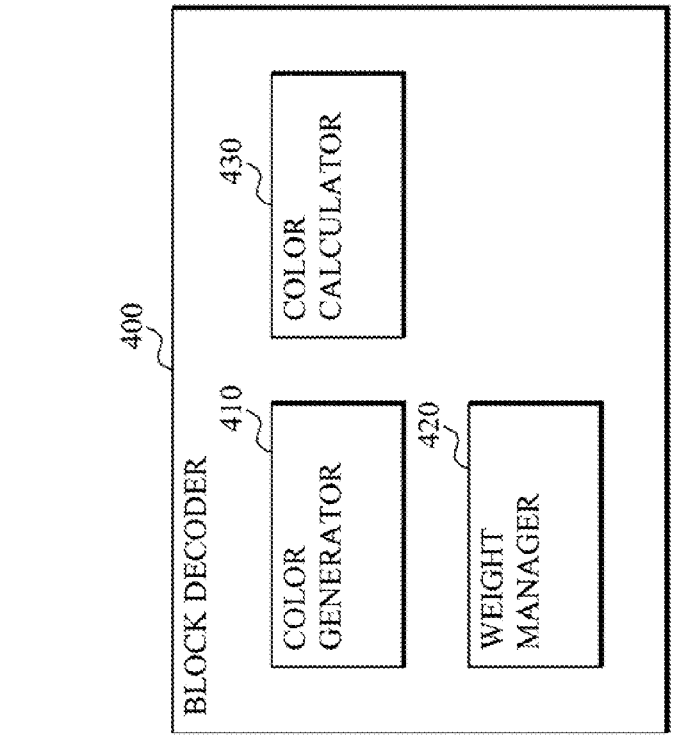
400
BLOCK DECODER
410
COLOR GENERATOR
420
WEIGHT MANAGER
430
COLOR CALCULATOR

Fig. 27

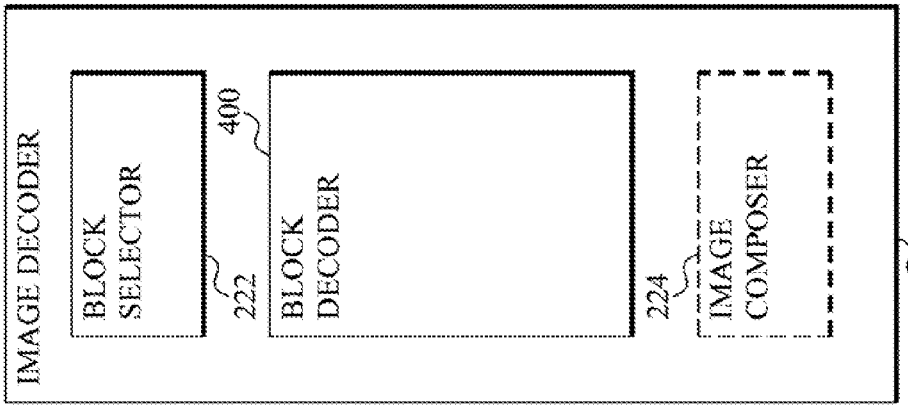
IMAGE DECODER
BLOCK SELECTOR
222
400
BLOCK DECODER
224
IMAGE COMPOSER
220

Fig. 26

WEIGHT BASED IMAGE PROCESSING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 11/915,669, filed Nov. 27, 2007, now U.S. Pat. No. 8,457,419, which was a 371 National Stage of International Application No. PCT/SE2006/000613, filed May 24, 2006, which claims the benefit of Swedish Application No. 0501260.4, filed May 27, 2005 and PCT/SE2005/001070 filed Jul. 1, 2005, the disclosures of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention generally refers to image processing, and in particular to methods and systems for encoding and decoding images.

BACKGROUND

Presentation and rendering of images and graphics on data processing systems and user terminals, such as computers, and in particular on mobile terminals have increased tremendously the last years. For example, three-dimensional (3D) graphics and images have a number of appealing applications on such terminals, including games, 3D maps and messaging, screen savers and man-machine interfaces.

A 3D graphics rendering process typically comprises three sub-stages. Briefly, a first stage, the application stage, creates several triangles. The corners of these triangles are transformed, projected and lit in a second stage, the geometry stage. In a third stage, the rasterization stage, images, often denoted textures, can be "glued" onto the triangles, increasing the realism of the rendered image. The third stage typically also performs sorting, using a z-buffer.

However, rendering of images and textures, and in particular 3D images and graphics, is a computationally expensive task in terms of memory bandwidth and processing power required for the graphic systems. For example, textures are costly both in terms of memory, the textures must be placed on or cached in fast on-chip memory, and in terms of memory bandwidth, a texture can be accessed several times to draw a single pixel.

In order to reduce the bandwidth and processing power requirements, an image (texture) encoding method or system is typically employed. Such an encoding system should result in more efficient usage of expensive on-chip memory and lower memory bandwidth during rendering and, thus, in lower power consumption and/or faster rendering.

Delp and Mitchell [1] developed a simple scheme, called block truncation coding (BTC) for image compression. Even though their applications were not texture compression per se, several of the other schemes described in this section are based on their ideas. Their scheme compressed grey scale images by considering a block of 4×4 pixels at a time. For such a block, two 8-bit grey scale values were stored, and each pixel in the block then used a single bit to index to one of these grey scales. This resulted in 2 bits per pixel (bpp).

A simple extension, called color cell compression (CCC), of BTC was presented by Campbell et al. [2]. Instead of using an 8-bit grey scale value, the 8-bit value is employed as an index into a color palette. This allows for compression of colored textures at 2 bpp. However, a memory lookup in the palette is required, and the palette is restricted in size.

The S3TC texture compression method by Iourcha et al. [3] is currently probably the most popular scheme. It is used in DirectX and there are extensions for it in OpenGL as well. Their work can be seen as a further extension of CCC. The block site for S3TC is 4×4 pixels that are compressed into 64 bits. Two base colors are stored as 16 bits each, and each pixel stores a two-bit index into a local color palette that consists of the two base colors and two additional colors in-between the base colors. This means that all colors lie on a line in RGB space. S3TC's compression rate is 4 bpp. One disadvantage of S3TC is that only four colors can be used per block.

Penney [4] introduces a radically different scheme that is used in the MBX graphics hardware platform for mobile phones. This scheme uses two low-resolution images and these are bilinearly upscaled during decompression. Each pixel also stores a blendfactor between these two upscaled images. Compression of 4 bpp and 2 bpp are described. 64 bits are used per block. The major disadvantage of Fenny's scheme, which makes it less attractive in real implementations, is that information is needed from neighboring image blocks during decompression, which severely complicates decompression.

PACKMAN is a recent texture compression method developed by Ström and Akenine-Möller [5]. It encodes a block of 2×4 texels (pixels) into 32 bits. Only one color is used per block, but in each pixel this color can be modified in intensity. The major goal of PACKMAN was to allow for minimal decompression complexity. In PACKMAN the chrominance is heavily quantized, which may introduce block artifacts.

In order to improve PACKMAN, Ström and Akenine-Möller developed an improved compression method denoted iPACKMAN//Ericsson Texture Compression (ETC) [6, 7]. In iPACKMAN/ETC two 2×4 image blocks are encoded in common, which allowed for differential encoding of the colors. This made it possible to have finer quantization of the colors, resulting in an increase in quality of about 3 dB. Hence, this compression method passed S3TC in terms of quality and is currently the highest quality texture compression method/system publicly known.

There is still a need to improve image compression and in particular in terms of compressing and decompressing problematic image blocks having certain color characteristics that cannot be efficiently handled by the prior art image processing schemes at a high quality. Such problematic image blocks include blocks having slowly varying transitions between two or more colors.

SUMMARY

The present invention overcomes these and other drawbacks of the prior art arrangements.

It is a general object of the present invention to provide an image processing scheme that effectively can handle image blocks having slowly varying transitions between two or more colors.

This and other objects are met by the invention as defined by the accompanying patent claims.

Briefly, the present invention invokes an image processing in the form of encoding (compressing) an image and decoding (decompressing) an encoded (compressed) image.

According to the invention, an image to be encoded is decomposed into a number of image blocks comprising multiple image elements (pixels, texels or voxels). An image block preferably comprises sixteen image elements and has a size of $2^m \times 2^n$ image elements, where in and n preferably are 2. Each image element in a block is characterized by an image

element property, preferably a color, e.g. a 24-bit RGB (red, green, blue) color. The image blocks are then encoded.

In this (lossy) block encoding, color weights are assigned to at least a subset of the image elements in the image block. At least two color codeword that are representations of at least two color values are then determined at least partly based on the assigned color weights. The generated encoded or compressed representation of the image block comprises the at least two color codewords, which can be regarded as quantized color values. As a consequence, the original colors of the image elements in the image block will be represented by color representations derivable from the at least two color values, in turn obtainable from the at least two color codewords. In addition, the color representations of the image elements in the at least one subset are derivable from combinations of the at least two color values weighted by assigned color weights.

This way of representing image blocks effectively handles smoothly varying transitions of at least two colors within an image block and such transitions and color slopes extending over neighboring blocks. Other advantages offered by the present invention will be appreciated upon reading of the below description of the embodiments of the invention.

During decoding or decompression, the at least two color values are determined based on the at least two color codewords. The color weights assigned to an image element to be decoded is then. Finally, a color representation to use for this image element is calculated based on the provided color weights and the determined at least two color values.

The present invention also teaches systems tbr encoding images and image blocks, systems for decoding encoded images and image blocks and user terminals housing such systems.

SHORT DESCRIPTION OF THE DRAWINGS

The invention together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

FIG. **1** is a flow diagram illustrating a method of compressing/encoding an image and image block according to the present invention;

FIG. **2** is an illustration of an example of an image block according to the present invention;

FIG. **3** is a drawing schematically illustrating assignment of color weights according to an embodiment of the present invention;

FIG. **4** is an illustration of a compressed representation of an image block according to at embodiment of the present invention;

FIG. **5** is a drawing schematically illustrating assignment of color weights according to another embodiment of the present invention;

FIG. **6** is an illustration of a compressed representation of an image block according to another embodiment of the present invention;

FIG. **7** is a drawing schematically illustrating assignment of color weights according to a further embodiment of the present invention;

FIG. **8** is a drawing schematically illustrating assignment of color weights according to yet another embodiment of the present invention;

FIG. **9** is a flow diagram illustrating an embodiment of the determining step of FIG. **1** in more detail;

FIG. **10** is a flow diagram of additional steps of the image encoding/compressing method of FIG. **1** according to a multi-mode implementation of the present invention;

FIG. **11** is a flow diagram illustrating embodiments of compressing steps of FIG. **10** in more detail;

FIG. **12**A is a diagram illustrating the distribution of colors of image elements of an image block that advantageously can be compressed according, to a mode of the multi-mode implementation;

FIG. **12**B is a diagram illustrating color representations generated according to a mode of the multi-mode implementation and suitable for representing the colors of the image elements illustrated in FIG. **12**A;

FIG. **13**A is a diagram illustrating the distribution of colors of image elements of another image block that advantageously can be compressed according to another mode of the multi-mode implementation;

FIG. **13**B is a diagram illustrating color representations generated according to another mode of the multi-mode implementation and suitable fir representing the colors of the image elements illustrated in FIG. **13**A;

FIGS. **14** to **17** are illustrations of compressed representations of an image block according to the multi-mode implementation;

FIG. **18** is a flow diagram of a method of decoding/decompressing a compressed image and image block according to the present invention;

FIG. **19** is a flow diagram illustrating additional steps of the decoding/decompressing method of FIG. **20** for a multi-mode implementation:

FIG. **20** is a flow diagram illustrating embodiments of the decompressing step of FIG. **19** in more detail;

FIG. **21** is a flow diagram illustrating another embodiment of the decompressing step of FIG. **19** in more detail;

FIG. **22** schematically illustrates an example of a user terminal with an image encoder and decoder according to the present invention;

FIG. **23** is a block diagram schematically illustrating an embodiment of an image encoder according to the present invention;

FIG. **24** is a block diagram schematically illustrating an embodiment of a block encoder according to the present invention;

FIG. **25** is a block diagram schematically illustrating another embodiment of a block encoder according to the present invention;

FIG. **26** is a block diagram schematically illustrating an embodiment of an image decoder according to the present invent on;

FIG. **27** is a block diagram schematically illustrating an embodiment of a block decoder according to the present invention; and

FIG. **28** is a block diagram schematically illustrating another embodiment of a block decoder according to the present invention.

DETAILED DESCRIPTION

Throughout the drawings, the same reference characters will be used for corresponding, or similar elements.

The present invention relates to image and graphic processing, and in particular to encoding or compressing images and image blocks and decoding or decompressing encoded (compressed) images and image blocks.

Generally, according to the invention, during image encoding, an image is decomposed or divided into a number of image blocks. Each such image block then comprises mul-

tiple image elements having, among others, a certain color. The image blocks are encoded or compressed to generate an encoded/compressed representation of the image.

When an encoded image or graphic primitive subsequently is to be rendered, e.g. displayed on a screen, the relevant image elements of the encoded image blocks are identified and decoded. These decoded image elements are then used to generate a decoded representation of the original image or graphics primitive.

The present invention is well adapted for usage with three-dimensional (3D) graphics, such as games, 3D maps and scenes, 3D messages, e.g. animated messages, screen savers, man-machine interfaces (MMIs), etc., but is not limited thereto. Thus, the invention could also be employed for encoding other types of images or graphics, e.g. one-dimensional (1D), two-dimensional (2D) or 3D images.

In 3D graphics processing, typically several triangles are created and the corresponding screen coordinates of the corners of these triangles are determined. Onto each triangle, an image (or portion of an image), or a so-called texture, is mapped ("glued"). The management of textures is, though, costly for a graphic system, both in terms of utilized memory for storage of textures and in terms of memory bandwidth during, memory accesses, when textures are fetched from the memory. This is a problem particularly for thin clients, such as mobile units and telephones, with limited memory capacity and bandwidth. As a consequence, a texture or image encoding, scheme is often employed. In such a scheme, a texture is typically decomposed or divided into a number of image blocks comprising multiple texels. The image blocks are then encoded and stored in a memory. Note that the size of an encoded (version of an) image block is smaller than the corresponding size of the uncoded version of the image block.

In the present invention the expression "image element" refers to an element in an image block or encoded representation of an image block. This image block, in turn, corresponds to a portion of an image or texture. Thus, according to the invention, an image element could be a texel (texture element) of a (1D, 2D, 3D) texture, a pixel of a (1D or 2D) image or a voxel (volume element) of a 3D image. Generally, an image element is characterized by certain image-element properties, such as a color value. Furthermore, in the following, the term "image" is used to denote any 1D, 2D or 3D image or texture that can be encoded and decoded by means of the present invention, including but not limited to photos, game type textures, text, drawings, etc.

The present invention provides an image processing that is in particular suitable for compressing and decompressing images and image blocks with slowly varying transitions between at least two colors. In the prior art schemes, discussed in the background section, a color palette comprising typically four color values is formed in color space by means of color codewords (S3TC) or color codeword(s) and intensity/color modifier codeword(s) (PACKMAN and iPACKMAN/ETC). Each image element then has a color index associated with one of the colors in the color palette. With such a solution, it is generally hard to processing image elements with slowly varying color transitions.

In clear contrast to these prior art schemes, the present invention assigns different color weights to image elements in an image block. Thereafter, colors to use for the image block are determined based at least partly on the assigned color weights. This means that the original colors of the image elements will be represented by color representations derivable from combinations of the determined colors weighted by the assigned color weights. This potentially allows utilizing unique color representations, depending on the assigned color weights, for each image element in the block, which in turn means a much larger color palette. In addition, the color weights can be set so that also problematic blocks having slowly varying color transitions can be represented at a high image quality.

Compression

FIG. **1** illustrates a (lossy) method of encoding an image according to the present invention in a first step S**1**, the image is decomposed or divided into a number of image blocks. Each such image block then comprises multiple image elements. In a preferred embodiment of the invention, an image block comprises sixteen image elements (pixels, texels or voxels) and has a size of $2^m \times 2^n$ image elements, where m=4−n and n=0, 1, 2, 3, 4. More preferably, m and n are both 2. It could also be possible to utilize an image block of size $2^m \times 2^n$ or $2^m \times 2^n \times 2^p$ image elements, where m, n, p are zero or positive integers with the proviso that not all of m, n, p may simultaneously be zero. FIG. **2** schematically illustrates an example of an image block **600** with sixteen image elements **610** according to the present invention. In an alternative embodiment of the present invention, the image is decomposed into a number of image sub-blocks, preferably having a size of 2×4 or 4×2 image elements. In such a case, two such sub-blocks could be handled together during compression to form a 4×4 block **600** as illustrated in FIG. **2**. Returning to FIG. **1**, the whole image block is preferably decomposed into (non-overlapping) image blocks in step S**1**. However, in some applications, only a portion of an image is encoded and, thus, only this portion is decomposed into image blocks.

The following steps S**2** and S**4** perform an encoding or compression of the image blocks. Firstly in step S**2**, color weights are assigned to at least a subset of the image elements in the image block, which is schematically illustrated by the line L**1**. The color weights are preferably determined based on the relative position the image elements of the at least one subset have in the image block. These color weights will be used during decompression for weighting different colors determined for the image block to generate color representations used for representing the original ("true") colors of the image elements. For example, assume that two colors (C_0 and C_1) are determined for the current image block. The color weights assigned in this step S**2** can then be w_0^{xy} and w_1^{xy} for image element having position (x,y) in the image block. During compression, the image representation of this image element will be $w_0^{xy}C_0+w_1^{xy}C_1$, thus a weighted combination, in this case a linear combination, of the two colors.

As is well known in the art a color typically comprises multiple color components, most often three color components depending on the proprietary color space utilized. For example, the colors could be RGB (Red, Green, Blue) colors, colors in the YIN space or YCrCb space, or any other proprietary color space used in image and graphics processing and management, in such a case, the multiple color weights assigned in step S**2** could regarded as a color weight vector

$$w^{xy} = \begin{bmatrix} w_{R0}^{xy} & w_{G0}^{xy} & w_{B0}^{xy} \\ w_{R1}^{xy} & w_{G1}^{xy} & w_{B1}^{xy} \end{bmatrix}.$$

In this case, the individual component elements in a weight vector could be set individually or at least could be equal. In the case $w_{R0}^{xy}=w_{B0}^{xy}=w_{G0}^{xy}$, the weight vector only comprises two weights

$$\begin{bmatrix} w_0^{xy} \\ w_1^{xy} \end{bmatrix}$$

per image element in this illustrative example.

The color weights are preferably assigned for each image element in at least one subset of the image elements in the blocks, which is represented by the line L**1**. In a first embodiment, the image block comprises N image elements, N is an integer larger than one, and the subset comprises M image elements, where 0≤M<N. This means that no color weights are assigned for the remaining N-M image element(s). In that case, the original color of this (these) remaining image element(s) is represented by one of the color codewords to be determined for the image block. However, this basically corresponds to setting all component elements of one of the color weight vectors to 1 and setting all component elements of the other color weight vector(s) to 0.

Therefore, in another preferred implementation or the present invention, color weights are assigned to all image elements in the block by basically repeating the step S**2** for each image element. In this embodiment, at least on the color weights assigned to at least one image elements is preferably different from 0, 1 and −1.

In a next step S**3**, at least two color codewords are determined for the image block based on or using the assigned color weights. These at least two color codewords are representations of at least two color values. As noted above, the color values could be RGB (Red, Green, Blue) colors, colors in the YUV space or YCrCb space, or any other proprietary color space used in image and graphics processing and management.

The color codewords are preferably in the same color format (space) as the image. However, in some cases, it may be useful to convert the image to a different color space. i.e. having the color codewords in a first color space and the original image in a second different color space.

In a first embodiment of the present invention, two color codewords are determined in this step S**3** based on the assigned color weights. However, in a preferred implementation of the present invention three, or sometimes four or mare, color codewords are instead determined based on the color weights. These multiple codewords then represent three, four or more, color values. According to the present invention, it is possible, by basing the color codeword determination on so the assigned color weights, to determine color codewords resulting in high image quality and allowing generation of color representations having slowly varying color transitions.

In a next step S**4**, the original colors of the multiple image elements in the block are represented by color representations derivable from the at least two color values, in turn being represented by the at least two color codewords determined in step S**3**. In addition, color representations of the image elements in the at least one subset, i.e. those image elements for which color weights were assigned in step S**2**, are derivable from combinations of the at least two color values weighted by the assigned color weights.

If the at least one subset comprises a first subset of the image element in the block, the color representations of these image elements are derivable from combinations of the at least two color values weighted by the assigned color weights. However, color representations of image elements in a second remaining subset of the image elements in the block are selected directly from the color values and therefore do not constitute combinations of multiple color values.

The steps S**2** to S**4** are preferably repeated for all image blocks provided during the decomposing of step S**1** (schematically illustrated by line L**2**). The result is then a sequence or file of encoded image blocks. The encoded image blocks (encoded representations of the image blocks) could be ordered in a file from left to right and top to bottom in the same order in which they were broken down in the block decomposing of step S**1**. The method then ends.

The encoded image could be provided to a memory for storage therein until a subsequent rendering, e.g. display, of the image. Furthermore, the encoded image could be provided as a signal of encoded block representations to a transmitter for (wireless or wired) transmission to another unit.

FIG. **3** is a schematic illustration of an image block **600** in an image or texture to be compressed according to the present invention. In this first implementation of the present invention, four color codewords are to be determined for the image block **600**. Each of the four color codewords represent a respective color value, the red components of which are denoted by R_0, R_1, R_2 and R_3. This embodiment basically allows for a bilinear upscaling but where all the colors needed for the bilinear upscaling are stored as a compressed representation for the image block. In this embodiment, the image elements **610** forming the corners of the image block **600** have color weights of only ones and zeros. Table 1 illustrates the color weights assigned to the image elements **610** in the block according to this embodiment of the present invention.

TABLE 1

color weights				
Position (x, y)	Color 0	Color 1	Color 2	Color 3
(0, 0)	1	0	0	0
(1, 0)	2/3	1/3	0	0
(2, 0)	1/3	2/3	0	0
(3, 0)	0	1	0	0
(0, 1)	2/3	0	1/3	0
(1, 1)	4/9	2/9	2/9	1/9
(2, 1)	2/9	4/9	1/9	2/9
(3, 1)	0	2/3	0	1/3
(0, 2)	1/3	0	2/3	0
(1, 2)	2/9	1/9	4/9	2/9
(2, 2)	1/9	2/9	2/9	4/9
(3, 2)	0	1/3	0	2/3
(0, 3)	0	0	1	0
(1, 3)	0	0	2/3	1/3
(2, 3)	0	0	1/3	2/3
(3, 3)	0	0	0	1

This means that the color representations of the image block illustrated in FIG. **3** and having assigned color weights according to Table 1 above will have red components according to Table 2 below.

TABLE 2

color combinations			
R_0	$\frac{2}{3}R_0 + \frac{1}{3}R_1$	$\frac{1}{3}R_0 + \frac{2}{3}R_1$	R_1
$\frac{2}{3}R_0 + \frac{1}{3}R_2$	$\frac{4}{9}R_0 + \frac{2}{9}R_1 + \frac{2}{9}R_2 + \frac{1}{9}R_3$	$\frac{2}{9}R_0 + \frac{4}{9}R_1 + \frac{1}{9}R_2 + \frac{2}{9}R_3$	$\frac{2}{3}R_1 + \frac{1}{3}R_3$
$\frac{1}{3}R_0 + \frac{2}{3}R_2$	$\frac{2}{9}R_0 + \frac{1}{9}R_1 + \frac{4}{9}R_2 + \frac{2}{9}R_3$	$\frac{1}{9}R_0 + \frac{2}{9}R_1 + \frac{2}{9}R_2 + \frac{4}{9}R_3$	$\frac{1}{3}R_1 + \frac{2}{3}R_3$
R_2	$\frac{2}{3}R_2 + \frac{1}{3}R_3$	$\frac{1}{3}R_2 + \frac{2}{3}R_3$	R_3

The blue and green components are preferably handled in the same way, i.e. basically by exchanging R_z with B_z or G_z, where z=0, 1, 2, 3.

As can be seen from Table 2, the red (green and blue) color components of twelve of the image elements are derivable as weighted linear combinations of at least of the color values (R_0, R_1, R_2, R_3) represented by the four color codewords. However, the red (green and blue) color components of the four corner image elements are each derived directly from one of the color values.

In this embodiment, when one move along the first row (R_0 to R_1), the third row (R_2 to R_3), the first column (R_0 to R_2) and the third column (R_1 to R_3) in Table 2, the red color component of the color representations of the image elements in these tows and columns change monotonically (unless the two end values are equal). For example, if $R_1>R_0$, the red component value increases monotonically along the first row, i.e. when moving from image element (0,0) to image element (0,3). Correspondingly, if $R_2<R_0$, the red component value decreased monotonically along the first column (from image element (0,0) to (3,0)). If the same color weights are used also for the green and/or blue color components also these will change monotonically for these row and columns. In the present invention, a row or column is denoted "one-dimensional array of image elements". This means that at least one color component of color representations change monotonically along at least one one-dimensional array of image elements. This allows for smooth transitions of colors and therefore image blocks having such color distributions can be represented by the present invention at a high image quality.

FIG. **4** illustrates a compressed representation **700** of the image block illustrated in FIG. **3** that has been compressed according to an embodiment of the present invention. The representation **700** (encoded or compressed image block) comprises a first color codeword **710**, a second color codeword **720**, a third color codeword **730** and a fourth color codeword **740**. Note that the mutual order of the codewords **710**, **720**, **730**, **740** of the encoded image block **700** may differ front what is illustrated in the figure.

The color weights assigned to image elements in the block are in this case pre-defined and will be used for all image blocks of the image compressed according to this embodiment of the present invention. This means that if all image blocks of an image are compressed according to the present invention, the color weights listed, in Table 1 will be used for all image blocks. However, note that the four color codewords can be different thr different blocks, thereby effectively resulting in different color representations for the image blocks.

It is however anticipated by the present invention that information of the color weights assigned to image elements in the image block can be included as a part of the compressed block representation **700**. For example, assume that there exist multiple weight sets that can be used for the image blocks. Each such weight set then comprises color weights assigned to image elements of at least one subset of the elements in the block. A first such weight set can include the color weights listed in Table 1 above. A second set can then have different weights for at least one of these image elements. In such a case, the compressed block representation **700** preferably comprises a weight set index or weight codeword representing the color weight set used for the current image block. A single bit (0_{bin} and 1_{bin}) can be used as weight codeword to discriminate between two weight sets, whereas two or more bits are required if more than two sets are available. In such a solution, different image blocks of an image can be compressed using different color weight distributions.

If 64 bits are assigned for the compressed image block **700**, 16 bits can be used per color codeword **710**, **720**, **730**, **740** and each color codeword **710**, **720**, **730**, **740** can be in the form of RGB565. More bits are preferably spent on the green components since the green component gives a disproportionate contribution to the perception of intensity.

However, the present invention is, as will thoroughly be discussed herein, preferably used as an auxiliary mode to the iPACKMAN/ETC scheme mentioned in the foregoing. In such a case, only 57 bits are available for encoding the four color codewords **710**, **720**, **730**, **740** (the remaining seven bits will be used as mode index for discriminating between this auxiliary mode, iPACKMAN/ETC and other auxiliary modes). Four color codewords **710**, **720**, **730**, **740** with three components each need to be encoded using only 57 bits and a possible solution could be to use a RGB554 format, resulting in 56 bits in total. The remaining bit can be used as weight codeword or boost one of the color components of one of the codewords **710**, **720**, **730**, **740**.

The embodiment present in FIGS. **3** and **4** and Table 1 has a drawback in that the color resolution obtainable for the color codewords **710**, **720**, **730**, **740** is rather low, especially when employing the present invention as a complement to iPACKMAN/ETC and each codeword **710**, **720**, **730**, **740** is in the format of RGB554. In this case, particularly the low resolution of the blue component will give rise to artifacts.

In a preferred implementation of the present invention, a plane is instead preferably used to approximate the color surface and provide the color weights instead of bilinear function. This is schematically illustrated. In FIG. **5**. Compared to FIG. **3** and the bilinear embodiment described above, only three color codewords are determined per image block **600**. This means that three color values are represented by these codewords and in FIG. **5**, the red components (R_0, R_H, R_V) of these color values have been illustrated.

The color representations and color weights of the image elements **610** in the image block **600** can be calculated using the following formula:

$$R(x,y)=\frac{x}{3}(R_H-R_0)+\frac{y}{3}(R_V-R_0)+R_0 \quad w_0^{xy}=1-\frac{x}{3}-\frac{y}{3}$$

$$G(x,y)=\frac{x}{3}(G_H-G_0)+\frac{y}{3}(G_V-G_0)+G_0 \quad w_H^{xy}=\frac{x}{3}$$

$$B(x,y)=\frac{x}{3}(B_H-B_0)+\frac{y}{3}(B_V-B_0)+B_0 \quad w_V^{xy}=\frac{y}{3}$$

This means that the color representations of the image elements **610** in positions (0,0), (0,3) and (3,0) can be directly selected from the color values represented by the three codewords, resulting in (R_0, G_0, B_0) for image element (0,0), (R_H, G_H, B_H) for image element (3,0) and (R_V, G_V, B_V) for image element (0,3) in this illustrative example. This corresponds to the following color weights to the these image elements w^{00}=[1 0 0], w^{30}=[0 1 0] and w^{03}=[0 0 1].

The color weights assigned to image blocks compressed according to this embodiment of the present invention are distributed among the image elements according to the Table 3 below.

TABLE 3

color weights			
Position (x, y)	Color 0	Color H	Color V
(0, 0)	1	0	0
(1, 0)	2/3	1/3	0
(2, 0)	1/3	2/3	0
(3, 0)	0	1	0
(0, 1)	2/3	0	1/3
(1, 1)	1/3	1/3	1/3
(2, 1)	0	2/3	1/3
(3, 1)	−1/3	1	1/3
(0, 2)	1/3	0	2/3
(1, 2)	0	1/3	2/3
(2, 2)	−1/3	2/3	2/3
(3, 2)	−2/3	1	2/3
(0, 3)	0	0	1
(1, 3)	−1/3	1/3	1
(2, 3)	−2/3	2/3	1
(3, 3)	−1	1	1

This means that the color representations of the image block illustrated in FIG. **5** and having assigned color weights according to Table 3 above will have red components according to Table 4 below.

TABLE 4

color representations			
R_0	$\frac{2}{3}R_0+\frac{1}{3}R_H$	$\frac{1}{3}R_0+\frac{2}{3}R_H$	R_H
$\frac{2}{3}R_0+\frac{1}{3}R_V$	$\frac{1}{3}R_0+\frac{1}{3}R_H+\frac{1}{3}R_V$	$\frac{2}{3}R_H+\frac{1}{3}R_V$	$-\frac{1}{3}R_0+R_H+\frac{1}{3}R_V$
$\frac{1}{3}R_0+\frac{2}{3}R_V$	$\frac{1}{3}R_H+\frac{2}{3}R_V$	$-\frac{1}{3}R_0+\frac{2}{3}R_H+\frac{2}{3}R_V$	$-\frac{2}{3}R_0+R_H+\frac{2}{3}R_V$
R_V	$-\frac{1}{3}R_0+\frac{1}{3}R_H+R_V$	$-\frac{2}{3}R_0+\frac{2}{3}R_H+R_V$	$-R_0+R_V+R_H$

The blue and green components are preferably handled in the same way, i.e. basically by exchanging R_z with B_z or G_z, where z=0, 1, 2, 3.

Also in this case the color components increase or decrease monotonically when moving along the first row and first column in Table 4.

FIG. **6** illustrates a compressed representation **700** of the image block illustrated in FIG. **5** that has been compressed according to this embodiment of the present invention. The representation **700** (encoded or compressed image block) comprises a rust color codeword **710**, a second color codeword **720** and a third color codeword **730**. Note that the mutual order of the codewords **710**. **720**, **730** of the encoded image block **700** may differ from what is illustrated in the figure.

The color codewords **710**, **720**, **730** can now be represented by the RGB676 color quantization, resulting ma total size for the three codewords of 57 bits. This means that this embodiment can advantageously be used as a complement and auxiliary mode to iPACKMAN/ETC as described above. RGB676 allows for a higher resolution as compared to the previous (RGB554) embodiment. Alternatively, if the present invention is used as a stand-alone scheme, the color codewords **710**, **720**, **730** can be represented as RGB777 and the remaining bit can be used as e.g. weight codeword or boost a color component of one of the codewords **710**, **720**, **730**.

Instead of employing three color codewords **710**, **720**, **730** allowing calculation of a color value directly from a codeword **710**, **720**, **730**, so-called differential codewords can be used. In such a case, the first color codeword **710** can be determined as described above, i.e. comprising three quantized color components, e.g. in the form of RGB777. The first color value (R_0, G_0, B_0) can then be obtained directly from this first codeword **710** by expanding the quantized color components. The other two codewords **720**, **730** instead code a distance in color space from this first color value. Thus, the two codewords **720**, **730** could represent $dR_HdG_HdB_H666$ and $dR_VdG_VdB_V666$, where each of the components dW_z, W=R, G, B and z=H, V, represents a number in the interval [−31, 32]. The other two color values are then obtained according to the following formula:

$R_{H/V}=R_0+dR_{H/V}$

$G_{H/V}=G_0+dG_{H/V}$

$B_{H/V}=B_0+dB_{H/V}$

The embodiments described in connection with FIGS. **3** and **5**, however, have a few drawbacks. Firstly, several of the assigned, color weights involve division by three or powers of three ($9=3^2$), which is rather expensive to perform when implementing the decompression in hardware. Another drawback with these patterns and color weight assignments is that it is difficult to create ramps of constant slope. For example, if R_H, G_H, B_H in one block is set to R_0, G_0, B_0 in the previous block, there will be two image elements having a same color representation next to each other, breaking the slope. Thus, although smooth color transition can be represented at a high quality within a given block, it is more difficult to encode such a smooth color transition over neighboring image blocks.

FIG. **7** illustrates an embodiment of the present invention, where the color weight assignment is performed in a way to solve the two drawbacks mentioned above. In this embodiment, the color weights are preferably selected so that only a single image element **610** in the block **600** has color weights constituting of a 1 and the rest 0. This means that this single image element **610**, preferably a corner image element, has its original color represented by a color value derived from only one of the three color codewords.

The way of positioning the color values as illustrated in FIG. **7**, results in the following formula for calculating, the color representations and color weights of the image elements **610** in the image block **600**:

$$R(x,y)=\frac{x}{4}(R_H-R_0)+\frac{y}{4}(R_V-R_0)+R_0 \quad w_0^{xy}=1-\frac{x}{4}-\frac{y}{4}$$

$$G(x,y)=\frac{x}{4}(G_H-G_0)+\frac{y}{4}(G_V-G_0)+G_0 \quad w_H^{xy}=\frac{x}{4}$$

$$B(x,y)=\frac{x}{4}(B_H-B_0)+\frac{y}{4}(B_V-B_0)+B_0 \quad w_V^{xy}=\frac{y}{4}$$

The color weights assigned to image blocks compressed according to this embodiment of the present invention are distributed among the image elements according to the Table 5 below.

TABLE 5

	color weights		
Position (x, y)	Color 0	Color H	Color V
(0, 0)	1	0	0
(1, 0)	¾	¼	0
(2, 0)	½	½	0
(3, 0)	¼	¾	0
(0, 1)	¾	0	¼
(1, 1)	½	¼	¼
(2, 1)	¼	½	¼
(3, 1)	0	¾	¼
(0, 2)	½	0	½
(1, 2)	¼	¼	½
(2, 2)	0	½	½
(3, 2)	−¼	¾	½
(0, 3)	¼	0	¾
(1, 3)	0	¼	¾
(2, 3)	−¼	½	¾
(3, 3)	−½	¾	¾

This means that the color representations of the image block illustrated in FIG. **7** and having assigned color weights according to Table 5 above will have red components according to Table 6 below.

TABLE 6

color representations			
R_0	$\frac{3}{4}R_0+\frac{1}{4}R_H$	$\frac{1}{2}R_0+\frac{1}{2}R_H$	$\frac{1}{4}R_0+\frac{3}{4}R_H$
$\frac{3}{4}R_0+\frac{1}{4}R_V$	$\frac{1}{2}R_0+\frac{1}{4}R_H+\frac{1}{4}R_V$	$\frac{1}{4}R_0+\frac{1}{2}R_H+\frac{1}{4}R_V$	$\frac{3}{4}R_H+\frac{1}{4}R_V$
$\frac{1}{2}R_0+\frac{1}{2}R_V$	$\frac{1}{4}R_0+\frac{1}{4}R_H+\frac{1}{2}R_V$	$\frac{1}{2}R_H+\frac{1}{2}R_V$	$-\frac{1}{4}R_0+\frac{3}{4}R_H+\frac{1}{2}R_V$
$\frac{1}{4}R_0+\frac{3}{4}R_V$	$\frac{1}{4}R_H+\frac{3}{4}R_V$	$-\frac{1}{4}R_0+\frac{1}{2}R_H+\frac{3}{4}R_V$	$-\frac{1}{2}R_0+\frac{3}{4}R_V+\frac{3}{4}R_H$

The blue and green components are preferably handled in the same way, i.e. basically by exchanging R_z with B_z or G_z, where z=0, 1, 2, 3.

Also in this case, the color components increase or decrease monotonically when moving along the first row and first column in Table 6.

The compressed block representation for this embodiment is illustrated FIG. **6** and the discussion in connection with this figure also applies to this embodiment.

In this embodiment, the color weights involve division by two or four, which is trivial to implement in hardware. In addition, the embodiment allows for continuity of color slope (color transitions) over block limits. This is possible by setting R_H (or R_V) in one block to R_0 of the previous block, which results in a perfect slope. A further advantage of this embodiment is that the precision of the color representations that are derivable from the color codewords and the color weights increases further since the color can change in steps of ¼ instead of ⅓ with each image element.

Further embodiments based on the same theme as FIG. **7** can be obtained by rotating the positions of R_0, R_H and R_V a quarter, a half or three quarters of a turn, respectively.

Generally, in a more general context, the color weights assigned to the image elements according to the present

invention can be selected, so that the color values represented by the color codewords could be regarded as all positioned within the image block (see FIGS. **3** and **5**), some are positioned within the image block and some are positioned outside the block (see FIG. **7**) or all could be positioned outside the block. The relative position of the color values in relation to the block defines the (planar) equation used for obtaining the color weights for the image elements. In a most preferred embodiment of the present invention, all the color values are not positioned on a same line (column/row) in the block.

It is anticipated by the present invention that color weights can be selected to represent positions of the color values in the block **600** so that the color values or points are not positioned in the middle of image elements **610**, which is schematically illustrated in FIG. **8**.

The formula for the plane will then be:

$$R(x,y)=2x(R_H-R_0)-2y(R_V-R_0)+R_0-3R_H+3R_V$$

$$G(x,y)=2x(G_H-G_0)-2y(G_V-G_0)+G_0-3G_H+3G_V$$

$$B(x,y)=2x(B_H-B_0)-2y(B_V-B_0)+B_0-3B_H+3B_V$$

and the color weights are represented by the equations:

$$w_0^{xy}=1-2x+2y$$

$$w_H^{xy}=-3+2x$$

$$w_V^{xy}=3-2y$$

The color weights assigned to image blocks compressed according to this embodiment of the present invention are distributed among the image elements according to the Table 7 below.

TABLE 7

color weights			
Position (x, y)	Color 0	Color H	Color V
(0, 0)	1	−3	3
(1, 0)	−1	−1	3
(2, 0)	−3	1	3
(3, 0)	−5	3	3
(0, 1)	3	−3	1
(1, 1)	1	−1	1
(2, 1)	−1	1	1
(3, 1)	−3	3	1
(0, 2)	5	−3	−1
(1, 2)	3	−1	−1
(2, 2)	1	1	−1
(3, 2)	−1	3	−1
(0, 3)	7	−3	−3
(1, 3)	5	−1	−3
(2, 3)	3	1	−3
(3, 3)	1	3	−3

The present invention, thus, involves assigning color weights to some or all image elements in the block and then determining color codewords based. On the weights, where color representations of the image elements are derivable from weighted, using the weights assigned to the image elements, combinations of color values represented by the codewords. This concept can of course be extended to different number of multiple color codewords and different color weight assignments. In a preferred implementation, at least one weight of at least one image element is different than 0, 1 and −1. Thus, employing three color codewords, means that color weights can be assigned so that a planar interpolation of color values is possible. If instead four or five codewords are employed for an image block, bilinear and Gaussian interpolation can be used, respectively. In the preferred implementation, the color weights are set to reflect that at least one of the color values represented by color codewords can be regarded as placed outside of the image block. This allows for good approximation of very slowly varying color—slower than if all color values are regarded as places inside the block (compare FIG. **5** and FIG. **7**).

FIG. **9** is a flow diagram illustrating an embodiment of the determining step of FIG. **1** in more detail. The method continues from step **S2** of FIG. **1**. In step **S10** candidate color codewords that are representations of candidate color values are selected. These candidate codewords can be selected randomly or be the smallest or largest possible candidate color codewords, such as a sequence of 19 0_{bin} (smallest possible codeword, representing color value (0, 0, 0)) or a sequence of 19 1_{bin} (largest possible codeword, representing color value (255, 255, 255)). The three color components R, G, B can be determined separately, i.e. basically running three parallel or subsequent processes. The discussion below is therefore limited to only one color component.

In a next step **S11**, the red color representation components for the image elements in the block obtained with this selection of candidate color codeword components is calculated using the assigned color weights. This corresponds to replacing R_0, R_H and R_V (R_0, R_1, R_2, R_3 and R_4) in the image blocks disclosed above with the red components of the candidate color value. The error of representing the red component of the image elements with these candidate color representation components are then estimated in step **S11**.

$$\varepsilon^2=\sum_{y=0}^{3}\sum_{x=0}^{3}\left(\begin{bmatrix} w_0^{xy} & w_H^{xy} & w_V^{xy}\end{bmatrix}\begin{bmatrix} R_0^c \\ R_H^c \\ R_V^c\end{bmatrix}-\overline{R}^{xy}\right)^2$$

In the error formula above, R_0^c, R_H^c, R_V^c represent the red component of three candidate color values represented by the three selected candidate color codeword components and $\overline{R}^{xy}$ is the original red color of the image element in position (x,y) within the block. In the formula above, the color weights and original color is image element specific, whereas the candidate color values are the same, for a given selection of candidate codeword components, for all image elements in the block. The calculated error value is then stored in an error memory in step **S12** together with a notification of the selected candidate color codewords.

The steps **S10** to **S12** are repeated for different selections of candidate color codeword components and if the estimated error value is smaller than the error value stored in the error memory, the new error value replaces the stored value and the candidate codeword components used for calculating this new smaller error value likewise replace the previously stored candidate codeword components.

This procedure is performed for all possible 18 bits for the red candidate components, resulting in 2^{18} steps. In addition, the procedure is performed for the green and blue color components, which in total involves $2^{18}+2^{19}+2^{18}$ operations. The respective red/green/blue codeword components resulting in the smallest error values are selected in step **S13** and used as color codewords according to the present invention. The method then continues to step **S4** of FIG. **1**.

In another embodiment, a least square approach is taken instead of an exhaustive search. This can be represented in matrix form according to below:

$$\begin{bmatrix} \bar{R}^{00} \\ \bar{R}^{10} \\ \\ \bar{R}^{33} \end{bmatrix} = \begin{bmatrix} w_0^{00} & w_H^{00} & w_V^{00} \\ w_0^{00} & w_H^{10} & w_V^{30} \\ & & \\ w_0^{33} & w_H^{33} & w_V^{33} \end{bmatrix} \begin{bmatrix} R_0 \\ R_H \\ R_V \end{bmatrix}$$

This can also be written as $\bar{y}=A\bar{x}$, where $\bar{y}$ is a vector comprising the 16 original red components of the image elements in the block, A is a matrix comprising the $3\times16=48$ color weights assigned to the image elements and $\bar{x}$ is a vector comprising the red components to be determined and quantized into red components of the color codewords. Thus, the vector $\bar{x}$ should be determined. This can be done according to the equation below:

$$\bar{x}=(A^TA)^{-1}A^T\bar{y}$$

The same procedure is also performed for the green and blue color components.

It is anticipated by the present invention that other techniques besides exhaustive search and least square can be used to determine the at least two codewords per image block according to the present invention.

As has been discussed in the foregoing, the present invention is advantageously used as a complement or auxiliary mode to the iPACKMAN/ETC compression scheme. In such a case, the present invention will be used for compressing and decompressing image blocks having slowly varying color transitions and in particular when there is a color slope extending over several, neighboring blocks. For other image blocks, iPACKMAN/ETC may instead be used or another auxiliary mode.

FIG. **10** schematically illustrates such an implementation. The method continues from step S**1** of FIG. **1**. The provided image block to be compressed is then processed according to different schemes, typically in parallel. In other words, the image block is in step S**20** compressed according to a first compression mode to generate a first compressed block representation. In a next step S**24**, an error value representative of representing the image block with this first compressed block is estimated. In addition, the same image block is further compressed according to at least one other compression mode, three other modes in the figure. Thus, a second, a third and a fourth compression mode is used for compressing the block in S**21**, S**22** and S**23** to generate a second, a third and a fourth compressed block representation, respectively. In steps S**25**, S**26** and S**27**, error values representative of representing the block with the second, third or fourth compressed block representation are estimated. Now four or in alternative embodiments two, three or more than four) different compressed representation are available. In the next step S**28**, one of these four compressed representations is selected and used as compressed version of the current block. This selection step is performed based on the error values calculated in the steps S**24**-S**27**. Thus, the compressed representation associated with the smallest error value will be selected in step S**28**. In a next step S**29**, a mode index representative of the compression mode used for generating the selected compressed representation is provided and is included in the compressed image block, i.e. in the bit sequence representing the image block. This procedure is preferably performed for each image block to be compressed. The method then ends.

This means that each image block of an image is preferably analyzed and compressed individually, which in most typical applications (depending on the actual image to be encoded), results in a mosaic of image blocks compressed according to the different modes. Thus, a first set of the image blocks is compressed according to the first mode, a second set of the blocks is compressed according to the second mode, a third block set is compressed according to the third mode and a fourth block set is compressed according to the fourth mode. For other applications only one, two or three of the modes will be used for the different image blocks.

In this embodiment, a compressed candidate block is generated per available compression mode. However, in another embodiment, the selection of compression mode to use for a current is block is performed prior to the actual block compressions. In such a case, a first analyzing step is performed where the original colors of the image elements in the block and in particular their distribution in color space is investigated and analyzed. The selection of compression mode is performed based on this analysis.

This embodiment is possible since, as will be discussed further below, the different available compression modes are particularly suitable and effective for given block types. For example, the scheme of the present invention is effective in handling blocks with slowly varying, color transitions. The iPACKMAN/ETC scheme is very efficient for handling image blocks where the colors of the image elements have rather similar chrominance but varying luminance. A third possible scheme could be THUMB [8], which also can be used as auxiliary mode to iPACKMAN/ETC. This scheme has two modes or so-called patterns, which are adapted for managing image blocks having two distinct chrominances (colors).

This embodiment has the advantage that only one and not four compressed candidate blocks need to be generated, though at the cost of a block and color analysis and a risk of selecting a non-optimal compression scheme.

In FIG. **10**, the first compression step S**20** can represent the steps S**2** to S**4** of FIG. **1**, i.e. assigning color weights, determining color codewords and representing the original colors of the image elements.

FIG. **11** is a flow diagram illustrating different embodiments of the other compression steps S**21**, S**22** and S**23** of FIG. **10** according to the iPACKMAN/ETC and THUMB schemes.

Starting with THUMP, the method continues from step S**1** in FIG. **1**. In a next step S**30**, a first and a second color codeword are determined. The first color codeword is a representation of a first color value and the second color codeword is likewise a representation of a second color value. The first and second color values are located on a first line in color space, preferably RGB space. This first line also has a first direction. In a next step S**31**, a color modifier codeword is provided. This modifier codeword is a representation of at least one color modifier applicable for modifying the first color value along a second line having a second direction in color space. By modifying the first color value with the at least one color modifier, multiple color representations are obtained along the second line. In this embodiment, the second direction is different from the first line, i.e. the first line and second line are not parallel.

A color index associated with a color representation selected, in step S**32**, from i) the multiple color representations along, the second line and ii) at least one color representation based on the second color value. This index selecting step is preferably performed for each image element in the block, which is schematically illustrated by the line L**4**.

The resulting compressed block representation of this mode will, thus, comprise the first and second color codewords, the color modifier codeword and a sequence of color indices.

The above-described THUMB scheme can actually, in turn, be run according to two modes or patterns, depending on how the colors of the image elements are distributed in color space. This means that THUMB occupies two of the four different modes in FIG. **10**, FIGS. **12-14**B disclose in more detail the usage of THUMB, in FIG. **12**A the original (16) colors of image elements in a block to be compressed are depicted in color space, it is clear from the figure that the colors are positioned in two clusters **2**, **4**, each containing multiple colors. Such a color distribution is advantageously handled with the H-pattern/mode of THUMB, which is illustrated in FIG. **12**B.

In FIG. **12**B, the first color value **10** represented by the first color codeword and the second color value **20** represented by the second color codeword are located on a first line **40** having a first direction **45**. Two color representations **30**, **32** are derivable from the first color value **10** using a color modifier represented by the color modifier codeword. These two color representations **30**, **32** and the first color value **10** are positioned on a second line **12** having a second direction **15**, which second direction **15** is different from the first direction **45**. In this H-pattern/mode, a color modifier represented by the color modifier codeword is likewise used for modifying the second color value **20** to obtain two color representations **31**, **33**. These two color representations **31**, **33** and the second color value **20** are positioned along a third line **22**, having as third direction **25**. In the illustrated example, the second **15** and third **25** directions are parallel.

The color indices selected for the image elements are then associated with one of the four color representations **30**, **31**, **32**, **33**.

FIG. **13**A is a corresponding diagram of an original color distribution effectively handled by a T-pattern/mode of THUMB. In the figure, the colors are positioned in two clusters **2**, **4** similar to FIG. **12**A. However, contrary to FIG. **12**A, one of the clusters **4** has a general circular shape instead of elliptical.

FIG. **13**B illustrates how THUMB handles such a situation. The first **10** and second **20** color values are positioned on the first line **40** having the first direction **45**. The first color value **10** is modified by a color modifier to generate a first **30** and a second **32** color representation positioned on the second line **12** having the second direction **15**. In this pattern/mode, the color representations available for the image elements are the first **30** and second **32** color representation, the first color value **10** and the second color value **20**. Each color index selected for the image elements is associated with one of these four possible representations.

If instead the iPACKMAN/ETC scheme is employed in step S**22** of FIG. **10**, a first color codeword is determined in step S**30** as a representation of a first color value. In this step S**30**, a second color codeword is also determined. However, this second codeword is a representation of a differential color. A second color value is then obtainable as a sum of the first color value and the differential color image elements in a first sub-block (2×4 or 4×2 image elements) are assigned the first color value whereas image elements in a second sub-block (2>4 or 4×2 image elements) are assigned the second color value.

An intensity codeword is provided in step S**31**, where the intensity codeword is a representation of a set of multiple intensity modifiers. These intensity modifiers are applicable for modifying the intensity of the first or second color value to generate multiple color representations. In a preferred implementation, the intensity codeword is a table index to an intensity table comprising multiple modifier sets. Where the modifier sets have different intensity modifiers. In step S**32**, an intensity index is selected for each image element in the block, where the intensity index is associated with an intensity modifier from the intensity modifier set represented by the intensity codeword.

FIG. **14** schematically illustrates a possible compressed block representation **700** for the iPACKMAN/ETC differential mode. The compressed block **700** includes the first color codeword **710** including three color components, red **712**, green **714** and blue **716**, preferably each represented by five bits. The second color or differential color codeword **720** likewise includes three components, red **722**, green **724** and blue **726**, preferably each represented by three bits. The compressed block **700** further includes two intensity codewords **750**A, **750**B, one for each 2×4/4×2 sub-block, preferably each of 3 bits. A sequence **760** of intensity indices, preferably one 2-bit intensity index per image element in the block, is also included in the compressed block **700**, resulting in 32 bits. A flipbit **770** defines whether the two sub-blocks of the image block is two 2×4 block or two 4×2 blocks, i.e. placed vertically flipbit=0_{bin} or horizontally flipbit=1_{bin}. iPACKMAN/ETC comprises two so-called default modes, of which one has been described and disclosed in the present document. A diffbit **780** discriminates between these two default modes. In FIGS. **14** to **17**, this diffbit **780** is equal and set to 1_{bin} (or 0_{bin}). Note that the mutual order of the codewords **710**, **720**, **750**A, **750**B, index sequence **760**, flipbit **770** and diffbit **780** of the encoded image block **700** may differ from what is illustrated in the figure. The total size of the compressed block is 64 bits.

In the iPACKMAN/ETC mode mentioned above, the color components **712**, **714**, **716** of the first color codeword **710** preferably each comprises 5 hits, basically representing any vale in the interval 0-31 (00000_{bin}-11111_{bin}). The components **722**, **724**, **726** of the second codeword **720** preferably each comprises 3 bits, which are used for representing a value in the interval −4 to +3. The color components of the second color value is obtainable by summing the components **712**, **714**, **716**; **722**, **724**, **726** of the two codewords:

$$\text{Red component}=R+dR$$

$$\text{Green component}=G+dG$$

$$\text{Blue component}=B+dB.$$

Since these color components represent intensity information, they are allowed to assume the values from 0 (no intensity) to 31 (full intensity). This means that bit combinations of the first color codeword **710** and the second color codeword **720** that result in that the additions R+dR, G+dG, B+dB will overflow, i.e. be <0 or >31 will never be used by the encoder operating in this iPACKMAN/ETC mode. This allows for introducing three auxiliary modes that can be used to complement iPACKMAN/ETC.

In the first auxiliary mode, the red component overflows, i.e. R+dR is smaller than zero or larger than 31. This happens if the first three bits of the red component **712** of the first color codeword **710** are equal and different from the first bit of the red component **722** of the second color codeword **720**.

In FIG. **15**, this principle is employed for using the H-pattern/mode of THUMB as an auxiliary mode to iPACKMAN/ETC. Thus, in this mode four bits **790** cannot be selected freely since the red components must overflow, which happens if these four bits **790** are equal to 1110_{bin} or 0001_{bin}. The compressed block representation **700** is preferably in total 64 bits, of which four has been used according to above. The remaining 60 bits are preferably divided between the including pans according to; 4 bits are assigned to each color com-

ponent **712**, **714**, **716**; **722**, **724**, **726** of the first **710** and second **720** color codewords. The color modifier codeword **750** comprises three bits, the diffbit **780** one bit (which has the same value as in FIG. **14**) and the color index sequence **760** preferably 32 bits.

A second auxiliary mode is obtainable if the green component overflows, i.e. G+dG is smaller than zero or larger than 31 and the red component is not allowed to overflow, i.e. $0 \leq R+dR \leq 31$. In this mode, the first bit of the red component **712** of the first color codeword in FIG. **14** is set different from the second or third bit of the red component **712**. In addition, the first three bits of the green component **714** of the first color codeword **710** must be equal and different from the first bit of the green component **724** of the second color codeword **720**.

In FIG. **16**, bit**0** (corresponds to first bit of red component in first color codeword in FIG. **14**), bit**8**-bit**10** (correspond to three first bits of green component in first color codeword in FIG. **14**) and bit**13** (corresponds to first bit of green component in second color codeword in FIG. **14**), collectively represented by **790** in the figure, cannot be set freely. Therefore, 59 bits remain to use for the other parts of the compressed block **700**. The division of bits among the color codewords **710**, **720**, color modifier codeword **750**, diffbit **780** and color index sequence **760** is preferably the same as for FIG. **15** except that the color modifier codeword **750** in this case only comprises two bits instead of three.

A third auxiliary mode using the scheme of the present invention is available if the blue component overflows, i.e. B+dB is smaller than zero or larger than 31, but the red and green components are not allowed to overflow. This means that the first bit of the red **712** and green **714** component of the first color codeword **710** in FIG. **14** must differ from the second or third component in the red **712** and green **714** components. In addition, the blue component overflows, i.e. B+dB is smaller than zero or larger than 31.

In FIG. **17**, therefore bit**0** (corresponds to first bit of red component in first color codeword in FIG. **14**), bit**8** (corresponds to the first hit of green component in first color codeword in FIG. **14**), bit**16**-bit**18** (correspond to three first bits of blue component in first color codeword in FIG. **14**) and bit**21** (corresponds to first bit of blue component in second color codeword in FIG. **14**), collectively denoted **790**, cannot be set freely. The red **712**, **722**, **732** and blue **716**, **726**, **736** components of three color codewords **710**, **720**, **730** are preferably assigned 6 bits each, whereas the corresponding green components **714**, **724**, **734** comprise 7 bits each and the than 780 is one bit. This amounts, in total, to 64 bits.

If the four different compressed representations illustrated in FIGS. **14**-**17** are possible, a mode index used for discriminating between the four modes preferably includes defined positions in the bit sequences. These bit positions include the three first bits of the red, green and blue component of the first color codeword and the first bit of the red, green and blue component of the second color codeword in FIG. **14**. In addition, the diffbit is preferably used to discriminate between the other available iPACKMAN/ETC mode. Note, however, that some of the hits of this mode index can be used for encoding the compressed block in the different modes.

Decompression

FIG. **18** illustrates a flow diagram of a method of decoding an encoded image or encoded version of an original image according to the present invention. The encoded image basically comprises several encoded representations of image blocks. These encoded block representations are preferably generated by the image encoding method discussed above.

The method generally starts by identifying encoded image block(s) to decode. It could be possible that all encoded image blocks of an encoded image should be decoded to generate decoded representation of the original image. Alternatively, only a portion of the original image is to be accessed. As a consequence, only a selected number of image blocks have to be decoded for more precisely, a selected amount of image elements of certain image blocks have to be decoded).

Once the correct encoded (representation(s) of) image block(s) is identified, step S**40** determines at least two color values based on the at least two color codewords in the compressed block representations. In a preferred implementation, this determining step involves expanding the quantized color of the color codeword, such as RGB676, into, preferably, 24 hits (RGB888). If the second color codeword comprises differential color components, these components are preferably added to corresponding components of the first color codeword before expansion to generate a second color value. In a preferred implementation of the present invention, the compressed block representation comprises three color codewords. This means that three color values are determined in step S**40** by extending each of the codeword.

The following to steps S**41** and S**42** are performed for each image element that is to be decoded, which is schematically illustrated by the line L**5**. In step S**41**, the color weights assigned to the image element to be decoded is provided. The color weights are preferably pre-defined weights, which depend on the actual position of the image element in the blocks:

$$w_0^{xy}=f_0(x,y)$$

$$w_H^{xy}=f_H(x,y)$$

$$w_V^{xy}=f_V(x,y)$$

Thus, all image blocks of the image compressed according to the present invention has preferably the same assignment of color weights so that an image element in, for example, position (2,1) in a first block will have the same color weights as an image element in position (2,1) in a second block.

However, it is anticipated by the present invention that there might be choice in the weight assignment that is performed block by block. In such a case, the compressed representation preferably comprises a weight codeword. This means that the weight provision in step S**41** is then performed based on the weight codeword, i.e. the set of color weights used for the current block is identified based on the weight codeword.

In a next step S**42**, the color representation used for representing the original color of the image element to be decoded is calculated based on the provided color weights and the determined at least two color values. In a preferred implementation, the color representation is calculated as weighted, using the provided weights, (linear) combination of the determined color values. In this context, all the color values are preferably used in the calculation, but it could be possible to use only a subset thereof.

Steps S**41** and S**42** could be performed for several image elements in the image block (schematically illustrated by line L**5**). It is anticipated by the invention that in some applications, only a single image element is decoded from a specific image block, multiple image elements of a specific image block are decoded and/or all the image elements of a specific block are decoded.

Steps S**40** to S**42** are then preferably repeated for all image blocks that comprise image elements that should be decoded (schematically illustrated by line L**6**). This means that the loop of steps S**40** to S**42** could be performed once, but most

often several times for different encoded image blocks and/or several times for a specific encoded image block.

In the optional step **S43**, a decoded representation of the original image, or a portion thereof, is generated based on the decoded image elements and blocks. The method then ends.

FIG. **19** is a flow diagram of a multi-mode implementation of the image and block decoding/decompression of the present invention. The method starts in step **S50**, where a decompression mode to use for the current block is selected based on a mode index. If the four different compressed representations illustrated in FIGS. **14-17** are possible, the mode index includes the diffbit, the three first bits of the red, green and blue component of the first color codeword and the first bit of the red, green and blue component of the second color codeword in FIG. **14**. Thus, the decoder investigates these bit positions in the bit sequence that constitutes the compressed block representation and selects which decompression mode based on the investigated bits. In a preferred implementation, a first compression mode is selected if the blue color component overflows but not the red and greens. A second and a third mode, is selected if the red component overflows or the green component overflows but not the red. If none of the components overflow, a fourth mode is selected in step **S50**.

If the first mode is selected in step **S50**, the method continues to step **S51**, where the block is decompressed according to this mode. This corresponds to performing the steps **S40**-**S42** illustrated in FIG. **18**. If a second, third or fourth mode is instead selected, the method continues to step **S52**, **S53** or **S54**.

FIG. **20** illustrates the decompression performed according to the THUMB mode. Starting in step **S60**, a first color value is determined based on the first color codeword. A second color value is determined based on the second color codeword in the step **S61**. These two color values are located on a first line having a first direction in color space (see FIGS. **12**B and **13**B). The color determinations of steps **S60** and **S61** preferably involve expanding the bit sequence of the codewords to generate the color values. A next step **S62** generates multiple color representations along a second line having a second direction in color space by modifying the first color value with at least one color modifier represented by the color modifier codeword. This second direction is different from the first direction. The next step **S63** is performed per image element to be decoded, which is schematically illustrated by the line L**7**. This step **S63** involves selecting, based on the color index sequence and more precisely the color index assigned to the relevant image element, a color representation from i) the multiple color representations along the second line and ii) at least one color representation bases on the second color value. In the H-pattern/mode, at least one color modifier provided based on the modifier codeword is also used for modifying the second color value along a third line having a third direction (different from the first direction) to generate multiple color representations. Thus, two sets of multiple color representations (one located on the second line and the other located on the third line) are available in this H-pattern and the color index of the image elements points to one of the representations in the two sets. In the T-pattern/mode, the multiple color representations on the second line are complemented with the first and second color value that can also be selected as color representations for the image elements. The method then continues to step **S43** of FIG. **18**.

If instead the iPACKMAN/ETC mode is selected based on the mode index, a color value is determined based on the first color codeword or the first and second color codeword in step **S70** of FIG. **21**. The color value is, if the image element to be decoded is present in a first (2×4/4×2) sub-block, determined based on the first color codeword, preferably by expanding the bit sequence of the codeword from RGB555 into RGB888. If the image element is instead is present in a second (2×4/4×2) sub-block, the color value is determined based on both the first and second color codeword, basically by adding the red components, green components and blue components of the first and second codewords and then expanding the result into RGB888 or alternatively first expanding the codeword components and then adding them). The compressed block comprises, in this mode, two intensity codewords, one per sub-block. The intensity codeword assigned to the sub-block comprising the image element to be decoded is used in step **S71** to provide a set of multiple intensity modifiers. This step preferably comprises providing, based on the intensity codeword, the modifier set from a table comprising multiple such modifier sets. An intensity modifier to use for the image element is selected in step **S72** from the provided modifier set based on the intensity index assigned to the image element. In the next step **S73**, the determined color value is intensity modified by the selected modifier to generate a color representation for the image element. The steps **S70** to **S73** are preferably repeated for all image elements in the block that are to be decoded. The method then continues to step **S43** of FIG. **18**.

Decompression Examples

Herein follows decompression examples using a bit sequence layout as illustrated in FIGS. **14** to **17**.

iPACKMAN/ETC

The compressed image block is represented by the following bit sequence:

10110 010 11010 110 00100 000 101 110 1 1

10 01 11 00 01 01 10 11 10 00 11 00 01 01 00 01

Firstly, bit**0**-bit**2**, bit**6**, bit**8**-**10**, bit**13**, bit**16**-**18**, bit**21** and the diffbit **780** are investigate to determine which decompression mode to use for this image block. Since none of the color components overflow and the diffbit **780** is set to 1, the differential default mode of iPACKMAN/ETC should be selected.

Firstly, the color components **712**, **714**, **716** of the first color codeword **710** are expanded into RGB888 to generate the first color value:

$$\text{Red: } 10110_{bin} \Rightarrow 101101_{bin}=181.$$

$$\text{Green: } 11010_{bin} \Rightarrow 11010110_{bin}=214$$

$$\text{Blue: } 00100_{bin} \Rightarrow 00100001_{bin}=33$$

The differential components **722**, **724**, **726** of the second color codeword **720** are added to these components to obtain the second color value:

$$\text{Red: } 010_{bin} \leftrightarrow 2 \Rightarrow 181+2=183$$

$$\text{Green: } 110_{bin} \leftrightarrow 2 \Rightarrow 214-2=212$$

$$\text{Blue: } 000_{bin} \leftrightarrow 0 \Rightarrow 33+2=33$$

The flipbit is set to 1_{bin}, which implies that the first color value is assigned to the eight image elements in the two uppermost rows of the 4×4 block, whereas the second color value is used for the eight image elements in the two lowest rows.

The two intensity codewords **750**A, **750**B point an intensity table, exemplified by Table 8 below:

TABLE 8

intensity table

intensity codeword	11_{bin}	10_{bin}	00_{bin}	01_{bin}
000_{bin}	−8	−2	2	8
001_{bin}	−12	−4	4	12
010_{bin}	−31	−6	6	31
011_{bin}	−34	−12	12	34
100_{bin}	−50	−8	8	50
101_{bin}	−57	−19	19	57
110_{bin}	−80	−28	28	80
111_{bin}	−127	−42	42	127

The first intensity codeword **750**A applicable for image elements in the first 2×4 sub-block is 101_{bin}, representing the intensity modifiers −57, −19, 19, 57. The second intensity codeword **750**B instead represents the intensity modifiers −80, −28, 28, 80.

The first image element in position (0,0) will have the following color representation:

(181,214,33)+(−19,−19,−19)=(162,195,14)

Correspondingly, the color representation of the last image element (in position (3,3)) is calculated as follows:

(183,212,33)+(80,80,80)=(255,255,113)

after clamping the calculated color component values between the minimum allowed value of 0 and the maximum value of 255.

This procedure is then continues for the rest of the image elements in the image blocks.

H-Pattern of THUMB

The compressed image block is represented by the follow bit sequence:

111 10 0 10 1101 0110 0010 0000 1011 101 1
10 01 11 00 01 01 10 11 10 00 11 00 01 01 00 01

In this case, the bits bit**0**-bit**2** are all equal and different from bit**5**, which means that the rod component overflows and a first auxiliary mode, i.e. THUMB H-pattern, should be used. The bit sequence presented above has the layout as illustrated in FIG. **15**.

The first and second color values are generated by expanding the components **712**, **714**, **716**; **722**, **724**, **726** of the two color codewords **710**, **720**:

Red 0: $1010_{bin} \Rightarrow 101010_{bin}$=170

Green 0: $1101_{bin} \Rightarrow 11011101_{bin}$=221

Blue 0: $0110_{bin} \Rightarrow 01100110_{bin}$=102

Red 1: $0010_{bin} \Rightarrow 00100010_{bin}$=34

Green 1: $0000_{bin} \Rightarrow 00000000_{bin}$0

Blue 1: $1011_{bin} \Rightarrow 10111011_{bin}$=187

The first color value is, thus, (**170**, **221**, **102**) and the second value is (34, 0, 187).

The modifier codeword **750** 101_{bin}=5 implies that the number 1_{bin} should be shifted five times leftwards to obtain 100000_{bin}32. This value is used to modify the two color values to obtain four color representations:

*C*0: (170,221,102)−(32,32,32)=(138,189,70)

*C*1: (170,221,102)+(32,32,32)=(202,253,134)

*C*2: (34,0,187)−(32,32,32)=(2,0,155)

*C*3: (34,0,187)+(32,32,32)=(66,32,219)

The first image element: has color index 10_{bin}, which implies that color representation C2 is used for this image element. This procedure is continued for the rest: of image elements (index $00_{bin} \leftrightarrow$ C0, $01_{bin} \leftrightarrow$ C2, $10_{bin} \leftrightarrow$ C2 and $11_{bin} \leftrightarrow$ C3).

T-Pattern THUMB

The compressed image block is represented by the ming bit sequence:

1 0110 010 000 1 0 1 100 0100 0001 0111 01 1
10 01 11 00 01 01 10 11 10 00 11 00 11 01 00 01

In this case, the green component overflows since bit**8**-bit**10** are equal and different from bit**12**. In addition, the red component does not overflow since bit**0** is different from bit**1**. This means that a second auxiliary decompression triode in the form of T-pattern of THUMB should be selected and the bit sequence is interpreted as having the layout of FIG. **16**.

The two color values are calculated in the same way as above for the P-pattern.

Red 0: $0110_{bin} \Rightarrow 01100110_{bin}$=102

Green 0: $0101_{bin} \Rightarrow 01010101_{bin}$=85

Blue 0: $0100_{bin} \Rightarrow 01000100_{bin}$=68

Red 1: $0100_{bin} \Rightarrow 01000100_{bin}$=68

Green 1: $0001_{bin} \Rightarrow 00010001_{bin}$=17

Blue 1: $0111_{bin} \Rightarrow 01110111_{bin}$=119

In this case the color modifier **750** includes only two bits $\mathbf{01}_{bin}$=1, which implies that the number 1_{bin} should be shifted leftward one: step to obtain 10_{bin}=2. Two of the four possible color representations are calculated using this modifier value, whereas the other two representations are equal to the two color values:

*C*0: (102,85,68)

*C*1: (102,85,68)−(2,2,2)=(100,83,66)

*C*2: (102,85,68)+(2,2,2)=(104,87,70)

*C*3: (68,17,119)

The first image element has color index 10_{bin}, which corresponds to C2. The procedure is then repeated for the rest of the image elements in the block.

PLANAR

The compressed image block is represented by the following bit sequence:

1 011001 0 0 101011 0 000 00 1 010 111001 1
1001110 001011 011100 0110001 010001

In this example, the blue component overflows since bit**16**-bit**18** are equal and different from bit**21**. In addition, bit**0** is different from bit**1** (red does not overflow) and bit**8** is different from bit**9** (green does not overflow). As a consequence, a fourth decompression mode as defined in the present invention, PLANAR, should be used.

In this example, three color values are calculated by expanding the color components **712**, **714**, **716**; **722**, **724**, **726**; **732**, **734**, **736** of the three color codewords **710**, **720**, **730** into RGB888.

R_0: $011001_{bin} \Rightarrow 1100101_{bin}$=101

G_0: $0101011_{bin} \Rightarrow 01010110_{bin}$=86

B_0: $000010_{bin} \Rightarrow 000010000_{bin}=8$

R_H: $111001_{bin} \Rightarrow 11100111_{bin}=231$

G_H: $1001110_{bin} \Rightarrow 10011101_{bin}=157$

B_H: $001011_{bin} \Rightarrow 00101100_{bin}=44$

R_V: $011100_{bin} \Rightarrow 01110001_{bin}=113$

G_V: $0110001_{bin} \Rightarrow 01100010_{bin}=98$

B_V: $010001_{bin} \Rightarrow 01000101_{bin}=69$

These color values are then weighted and combined according to the teachings of Table 6 above. The color representation for the first image element (0,0) is simply the first value (101, 6, 8). The color representation for image element (1,0) is three fourths thirds of the first color value and one fourth of the second color value, i.e.

$$\frac{3}{4}(101, 86, 8) + \frac{1}{4}(231, 157, 44) = (133, 104, 17).$$

This procedure is continued for the rest of the image elements to provide a decoded representation of the image block.

Implementation Aspects

The image encoding (image block encoding) and image decoding (image block decoding or processing scheme according to the present invention could be provided in a general data processing system, e.g. in a user terminal or other unit configured for processing and/or rendering images. Such a terminal could be a computer, e.g. PC, a game console or a thin client, such as a Personal Digital Assistance (PDA), mobile unit and telephone.

User Terminal

FIG. **22** illustrates a user terminal **100** represented by a mobile unit. However, the invention is not limited to mobile units by could be implemented in other terminals and data processing units, such as PC computers and game consoles. Only means and elements in the mobile unit **100** directly involved in the present invention are illustrated in the figure.

The mobile unit **1110** comprises a (central) processing unit (CPU) **200** for processing data, including image data, within the mobile unit **100**. A graphic system **130** is provided in the mobile unit **100** for managing image and graphic data. In particular, the graphic system **130** is adapted for rendering or displaying images on a connected screen **120** or other display unit. The mobile unit **100** also comprises a storage or memory **140** for storing data therein. In this memory **140** image data may be stored, in particular encoded image data (encoded image blocks) according to the present invention.

An image encoder **210** according to the present invention is provided in the mobile unit **100**. This encoder **210** is configured for encoding an image or texture into an encoded representation of the image (or texture). As was discussed above, such an encoded representation comprises a sequence or file of multiple encoded image blocks. This image encoder **210** may be provided as software running on the CPU **200**, as is illustrated in the figure. Alternatively, or in addition, the encoder **210** could be arranged in the graphic system **130** or elsewhere in the mobile unit **100**.

An encoded representation of an image from the block encoder **210** may be provided to the memory **140** over a (memory) bus **150**, for storage therein until a subsequent rendering of the image. Alternatively, or in addition, the encoded image data may be forwarded to an input and output (I/O) unit **110** for (wireless or wired) transmission to other external terminals or units. This I/O unit **110** can also be adapted for receiving image data from an external unit. This image data could be an image that should be encoded by the image encoder **210** or encoded image data that should be decoded. It could also be possible to store the encoded image representation in a dedicated texture memory provided, for example, in the graphic system **130**. Furthermore, portions of the encoded image could also, or alternatively, be (temporarily) stored in a texture cache memory, e.g. in the graphic system **130**.

An image decoder **220** according, to the present invention is provided in the mobile unit **100** for decoding an encoded image in order to generate a decoded image representation. This decoded representation could correspond to the whole original image or a portion thereof. The image decoder **220** provides decoded image data to the graphic system **130**, which in turn typically processes the data before it is rendered or presented on the screen **120**. The image decoder **220** can be arranged in the graphic system **130**, as is illustrated in the figure. Alternatively, or in addition, the decoder **200** can be provided as software running on the CPU **200** or elsewhere in the mobile unit **100**.

The mobile unit **100** could be equipped with both an image encoder **210** and an image decoder **220**, as is illustrated in the figure. However, for some terminals **100** it could be possible to only include an image encoder **210**. In such a case, encoded image data could be transmitted to another terminal that performs the decoding and, possibly, rendering of the image. Correspondingly, a terminal **100** could only include an image decoder **220**, i.e. no encoder. Such a terminal **100** then receives a signal comprising encoded image data from another terminal and decodes it to generate a decoded image representation. Thus, the encoded image signal could be wirelessly be transmitted between terminals using radio transmitter and receiver. Alternatively, other techniques for distributing images and encoded image representations between terminals according to the invention could be employed, such as Bluetooth®, IR-techniques using IR ports and wired transferring of image data between terminals. Also memory cards or chips that can be connected and exchanged between terminals could be used for this image data inter-terminal distribution.

The units **110**, **130**, **200**, **210** and **220** of the mobile unit **100** may be provided as software, hardware or a combination thereof.

Image Encoder

FIG. **23** illustrates a block diagram of an embodiment of an image encoder **210** according to the present invention. The encoder **210** typically comprises an image decomposer **215** for decomposing or dividing an input image into several image blocks. The decomposer **215** is preferably configured for decomposing the image into image blocks comprising sixteen image elements (pixels, texels or voxels), i.e. having a general size of 4×4 image elements. This decomposer **215** could be adapted for decomposing different input images into image blocks with different sizes. In such a case, the decomposer **215** preferably receives input information, enabling identification of which image block format to use for a given image.

This embodiment of the image encoder **210** comprises a single block encoder **300**. This block encoder **300** encodes the image block(s) received from the image decomposer to generate encoded block representation(s). The overall sin of the block representation is smaller than the corresponding site of the uncoded image block. The block encoder **300** is prefer-

ably configured for processing (encoding) each image block from the decomposer **215** sequentially.

In an alternative implementation, the encoder **210** includes multiple block encoders **300** for processing multiple image blocks from the image decomposer **215** in parallel, which reduces the total image encoding time.

The units **215** and **300** of the image encoder **210** may be provided as software, hardware or a combination thereof. The units **215** and **300** may be implemented together in the image encoder **210**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the mobile unit.

Block Encoder

FIG. **24** illustrates a block diagram of an embodiment of a block encoder **300** according to the present invention, such as the block encoder of the image encoder in FIG. **23**. The encoder **300** comprises a weight assigner **310** for assigning color weights to at least one subset of the image elements in an image block that is to be compressed. In a preferred implementation, the weight assigner **310** assigns Z color weight per image element in the block, where Z is a multiple number which is equal to the number of color codewords a color quantizer **320** determines for the image block. In another preferred embodiment, the assigner **310** assigns color weights to the image elements in a block so that color component values of at least one color component of color representations used for representing the original colors of the image elements change monotonically along a row or/and column of image elements in the block. The weight assignment performed by the assigner **310** of the block encoder **300** to image elements in a block is preferably conducted based on the position of the image elements, i.e. the relative coordinates of the image elements in the block.

The color quantizer **320** of the block encoder **300** is arranged for determining, based at least partly on the color weights assigned by the assigner **310**, at least two color codewords for the image block. In a preferred implementation, the color quantizer **320** determines three color codewords, preferably three RGB676 codewords.

The units **310** and **320** of the block encoder **300** may be provided as software, hardware or a combination thereof. The units **310** and **320** may be implemented together in the block encoder **300**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the image encoder.

FIG. **25** is a schematic block diagram of another embodiment of a block encoder **300** according to the present invention. This block encoder **300** is adapted for operating according to different compression modes, preferably four different modes. In a first compression mode, the weight assigner **310** and color quantizer **320** are operated according to the discussion above in connection with FIG. **24**. This, thus, results in a compressed image block comprising three color codewords and a mode index, which is to be described thither below. An example of such a compressed block is illustrated in FIG. **17**.

In the iPACKMAN/ETC compression mode, the color quantizer **320** is operated for determining a first color codeword that is a representation of a first color value and for determining a second color codeword as a representation of a differential color, which can be added to the first color value to obtain a second color value. A modifier quantizer **340** is operated in this mode for determining at least one, preferably two, intensity codewords as representation of at least one set of multiple intensity modifiers used for modifying the first or second color value to obtain color representations. The intensity codewords are preferably table indices to a modifier table **500** comprising multiple such modifier sets. An index selector **350** is provided in the block encoder **300** for determining, for each image element in the block, an intensity index associated with one of the intensity modifiers in the modifier set(s) represented by the intensity codeword(s).

In the two THUMB modes, the color quantizer **320** determines a first color codeword as a representation of a first color value. In addition, the quantizer **320** determines a second codeword as representation of a second color value, where these two values are located on a first line with a first direction in color space. The modifier quantizer **340** is operated in this mode for providing a color modifier codeword as a representation of at least one color modifier applicable for modifying the first color value along a second line having a second direction in color space. This color modification results in multiple color representations along the second line. The second and first directions are non-parallel. The index selector **350** then selects, for each image element, a color index associated with a color representation selected from i) the color representations along the second line and ii) at least one color representation based on the second color value.

In a preferred implementation, multiple compressed candidate representations are determined for a given image block, one representation per compression mode. A mode selector **360** is then implemented for selecting which of the candidate representations that should be used as compressed representation for the image block. This selection is preferably performed based on a comparison of error estimates, one such estimate per compression mode. The candidate that is leads to a smallest error is preferably selected by the mode selector **360**. A mode index manager **370** then compiles a mode index representative of the compression mode resulting in the smallest error, i.e. the mode used when generating the candidate selected by the mode selector **360**. This mode index, constitutes a part of the compressed image block.

The units **310** to **370** of the block encoder **300** may be provided as software, hardware or a combination thereof. The units **310** to **370** and **500** may be implemented together in the block encoder **300**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the image encoder.

Image Decoder

FIG. **26** illustrates a block diagram of an embodiment of an image decoder **220** according to the present invention. The image decoder **220** preferably comprises a block selector **222** that is adapted for selecting, e.g. from a memory, which encoded image block(s) that should be provided to a block decoder **400** for decoding. The block selector **222** preferably receives input information associated with the encoded image data, e.g. from a header or a rendering engine. An address of an encoded image block having, the desired image element(s) is then computed based on the input information. This computed address is preferably dependent upon the image-element (pixel, texel or voxel) coordinates within an image. Using the address, the block selector **222** identifies the encoded image block from the memory. This identified encoded image block is then fetched from the storage and provided to the block decoder **400**.

The (random) access to image elements of an image block advantageously enables selective decoding of only those portions of an image that are needed. Furthermore, the image can be decoded in any order the data is required. For example, in texture mapping only portions of the texture may be required and these portions will generally be required in a non-sequential order. Thus, the image decoding of the present invention can with advantage by applied, to process only a portion or section of an image.

The selected encoded image block is then forwarded to the block decoder **400**. In addition to the image block, the decoder **400** preferably receives information specifying which image elements of the block that should be decoded. The information could specify that the whole image block, i.e. all image elements therein, should be decoded. However, the received information could identify only a single or a few of the image elements that should be decoded. The block decoder **400** then generates a decoded representation of the image element(s) in the block. This decoded representation is preferably a P-bit color, where P is the number of bits per image element in the original image, e.g. a 24-bit RGB color.

An optional image composer **224** could be provided in the image decoder **220**. This composer receives the decoded image elements from the block decoder **400** and composes them to generate a pixel that can be rendered or displayed on a screen. This image composer **224** could alternatively be provided in the graphic system.

Alternatively, the image decoder **220** comprises multiple block decoders **400**. By having access to multiple block decoders **400**, the image decoder **220** can process (decode) multiple encoded image blocks in parallel. These multiple block decoders **400** allow for parallel processing that increases the processing performance and efficiency of the image decoder **220**.

The units **222**, **224** and **400** of the image decoder **220** may be provided as software, hardware or a combination thereof. The units **222**, **224** and **400** may be implemented together in the image decoder **220**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the user terminal.

Block Decoder

FIG. **27** is an illustration of an embodiment of a block decoder **400** according, to the present invention. The block decoder **400** comprises as color generator **410** that generates at least two color values based on the at least two color codewords in the compressed block representation. This color generator **410** is preferably configured for expanding, or extending the quantized color components of the color codewords into, preferably, RGB888. A weight manager **420** is arranged in the block decoder **400** for providing, for each image element that should be decoded, color weights assigned to the image element(s). In a preferred implementation, corresponding image elements in a given position in different image blocks have same assigned color weights. Thus, the color weights are dependent on the coordinates or positions of the image elements in the block but do not change for different blocks compressed according to the present invention. The weight manager **420** therefore preferably provides color weights based on image elements positions/coordinates in the image block.

A color calculator **430** is connected to the color generator **410** and the weight manager **420** and uses the provided color weights and the generated color values for determining a color representation to use as a representation of the original color of the image element. The calculator **430** is preferably implemented for combining the color values from the generator **410** but weighted with the color weights from the weight manager **420**.

The units **410** to **430** of the block decoder **400** may be provided as software, hardware or a combination thereof. The units **410** to **430** may be implemented together in the block decoder **400**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the image decoder.

FIG. **28** is a schematic block diagram of another embodiment of a block decoder **400** according to the present invention adapted for multi-mode operation. The block decoder **400** comprises a mode selector **460** that selects which decompression mode out of multiple available modes, preferably four modes, to use when decompressing the current compressed block representation. This mode selector **460** uses a mode index in the compressed block for selecting the correct mode.

If the selector **460** selects a first decompression mode, the color generator **410**, weight manager **420** and color calculator **430** are operated as described in the foregoing in connection with FIG. **27**.

If the selector **460** instead selects a second decompression mode, corresponding to iPACKMAN/ETC, the color generator **410** determines a color value based on the first color codeword or based on the first and second color codeword (depending on the actual position of the image element in the block). In the former case, the quantizer component colors are simply extended into preferably RGB888. In the latter case, the differential components of the second codeword are added to the color components derivable from the first codeword to determine the color value. A modifier manager **470** is provided in the block decoder **400** for providing, based on one of the at least one intensity codewords, a set of multiple intensity modifiers, preferably from a modifier table **500**. A color selector **450** selects, using an intensity index associated with the current image element, one of the intensity modifiers from the provided set. A color modifier **440** then uses this selected intensity modifier to intensity modify the color value to calculate a color representation for the image element.

If the THUMB modes are selected by the mode selector **460**, the color generator **410** determines a first color value using the first color codeword and determines a second color value based on the second color codeword. The two values are located on a first line having a first direction in color space. The color modifier **440** generates multiple color representations along a second line having a second different direction by modifying the first color value with at least one color modifier represented by the color modifier codeword. The color selector **450** then selects, based on the color index sequence, a color representation from i) the multiple color representations along the second line and ii) at least one color representation based on the second color value.

The units **410** to **470** of the block decoder **400** may be provided as software, hardware or a combination thereof. The units **410** to **470** and **500** may be implemented together in the block decoder **400**. Alternatively, a distributed implementation is also possible with some of the units provided elsewhere in the image decoder.

It will be understood by a person skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

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The invention claimed is:

1. A method of processing a compressed representation of an image block comprising multiple image elements, said compressed representation comprising at least two color codewords, and said method in a system comprising the steps of:

determining, by the system, at least two color values based on said at least two color codewords, wherein said color codewords are quantized color values;

for at least one image element in said image block:

providing, by the system, color weights assigned to said at least one image element based on a position of said image element within said image block; and

calculating, by the system, a color representation based on said provided color weights and said determined at least two color values.

2. The method according to claim **1**, wherein said providing step comprises providing said color weights based only on a position of said image element within said image block.

3. The method according to claim **1**, wherein said providing step comprises providing color weights defined in such a way that color component values of at least one color component of color representations change monotonically along a row or column of image elements in said image block.

4. The method according to claim **1**, wherein said compressed representation comprises three color codewords and said determining step comprises determining three color values based on three color codewords, and said calculating step comprises calculating said color representation based on said provided color weights and at least two color values of said determined three color values.

5. The method according claim **1**, further comprising the steps of:

selecting, by the system, a decompression mode based on a mode index in said compressed block representation; and

decompressing, by the system, said compressed representation according to said selected decompression mode,

wherein said decompressing step comprises said determining, providing and calculating steps if a first decompression mode is selected based on said mode index.

6. A method of decoding an encoded image that comprises encoded representations of image blocks, each image block comprising multiple image elements, said method in a system comprising the steps of:

processing, by the system, compressed representations of image blocks to generate multiple color representations of image elements, wherein each compressed representation comprising at least two color codewords, and wherein the processing of each compressed representation of an image block comprises:

determining at least two color values based on at the least two color codewords, wherein said color codewords are quantized color values;

for at least one image element in said image block:

providing color weights assigned to said at least one image element based on a position of said image element within said image block; and

calculating a color representation based on said provided color weights and said determined at least two color values; and

generating, by the system, a decoded representation of said encoded image by composing said multiple color representations of image elements.

7. A system for processing a compressed representation of an image block comprising multiple image elements, said compressed representation comprising at least two color codewords, and said system comprising:

a color generator for determining at least two color values based on said at least two color codewords, wherein said color codewords are quantized color values;

a weight manager for providing, for at least one image element in said image block, color weights assigned to said at least one image element, wherein said weight manager is arranged for providing said color weights based on a position of said at least one image element within said image block; and

a color calculator for calculating a color representation based on said provided color weights and said determined at least two color values.

8. The system according to claim **7**, wherein said weight manager is arranged for providing said color weights based only on a position of said at least one image element within said image block.

9. The system according to claim **7**, wherein said compressed representation comprises three color codewords and said color generator is arranged for determining three color values based on three color codewords, and said color calculator is arranged for calculating said color representation based on said provided color weights and at least two color values of said determined three color values.

10. The system according claim **7**, further comprising a mode selector for selecting a decompression mode based on a mode index in said compressed representation, said color generator, weight manager and color calculator are operated in a first decompression mode.

11. The system according to claim **7**, wherein the system comprises a user terminal.

12. A system for decoding an encoded image that comprises encoded representations of image blocks, each image block comprising multiple image elements, said system comprising:

a processing system for processing compressed representations of image blocks to a generate multiple color representations of image elements, wherein each compressed representation comprising at least two color codewords, and wherein the processing system processes each compressed representation of an image block utilizing:

a color generator for determining at least two color values based on said at least two color codewords, wherein said color codewords are quantized color values;

a weight manager for providing, for at least one image element in said image block, color weights assigned to said at least one image element, wherein said weight manager is arranged for providing said color weights based on a position of said at least one image element within said image block; and

a color calculator for calculating a color representation based on said provided color weights and said determined at least two color values; and

an image composer for generating a decoded representation of said encoded image by composing said multiple color representations of image elements.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,087,365 B2
APPLICATION NO. : 13/826578
DATED : July 21, 2015
INVENTOR(S) : Ström

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Drawings

In Fig. 11, Sheet 6 of 15, delete "STEP S25, S27 OR S27" and insert -- STEP S25, S26 OR S27 --, therefor.

In Fig. 19, Sheet 11 of 15, for Step "S53", in Line 2, delete "BLOCK IN 2ND" and insert -- BLOCK IN 3RD --, therefor.

In the Specification

In Column 1, Line 38, delete "sorting," and insert -- sorting --, therefor.

In Column 2, Line 5, delete "block site" and insert -- block size --, therefor.

In Column 2, Line 12, delete "Penney" and insert -- Fenney --, therefor.

In Column 2, Line 59, delete "invokes" and insert -- involves --, therefor.

In Column 2, Line 66, delete "in and n" and insert -- m and n --, therefor.

In Column 3, Line 31, delete "systems tbr" and insert -- systems for --, therefor.

In Column 3, Line 52, delete "at embodiment" and insert -- an embodiment --, therefor.

In Column 4, Line 8, delete "according," and insert -- according --, therefor.

In Column 4, Line 20, delete "fir" and insert -- for --, therefor.

In Column 4, Line 30, delete "implementation:" and insert -- implementation; --, therefor.

Signed and Sealed this
Nineteenth Day of April, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

In Column 4, Line 49, delete "invent on;" and insert -- invention; --, therefor.

In Column 4, Line 60, delete "corresponding," and insert -- corresponding --, therefor.

In Column 5, Line 24, delete "during," and insert -- during --, therefor.

In Column 5, Lines 27-28, delete "encoding," and insert -- encoding --, therefor.

In Column 6, Line 9, delete "invention in" and insert -- invention. In --, therefor.

In Column 6, Line 33, delete "Firstly" and insert -- Firstly, --, therefor.

In Column 6, Line 50, delete "art" and insert -- art, --, therefor.

In Column 6, Line 54, delete "YIN" and insert -- YUV --, therefor.

In Column 7, Line 21, delete "or the" and insert -- of the --, therefor.

In Column 7, Line 39, delete "space." and insert -- space, --, therefor.

In Column 7, Line 45, delete "four or mare," and insert -- four or more, --, therefor.

In Column 7, Line 50, delete "on so" and insert -- on --, therefor.

In Column 9, Line 31, delete "tows" and insert -- rows --, therefor.

In Column 9, Line 55, delete "front what" and insert -- from what --, therefor.

In Column 9, Line 61, delete "listed," and insert -- listed --, therefor.

In Column 9, Line 63, delete "thr" and insert -- for --, therefor.

In Column 10, Line 62, delete "illustrated. In" and insert -- illustrated in --, therefor.

In Column 12, Line 13, delete "rust" and insert -- first --, therefor.

In Column 12, Line 15, delete "710." and insert -- 710, --, therefor.

In Column 12, Line 20, delete "ma total" and insert -- in a total --, therefor.

In Column 13, Line 10, delete "assigned," and insert -- assigned --, therefor.

In Column 13, Line 51, delete "calculating," and insert -- calculating --, therefor.

In Column 15, Line 1, delete "selected," and insert -- selected --, therefor.

In Column 15, Line 55, delete "based. On" and insert -- based on --, therefor.

In Column 17, Line 50, delete "or" and insert -- (or --, therefor.

In Column 18, Line 21, delete "varying," and insert -- varying --, therefor.

In Column 19, Line 5, delete "FIGS. 12-14B" and insert -- FIGS. 12A-12B --, therefor.

In Column 19, Line 6, delete "THUMB, in" and insert -- THUMB. In --, therefor.

In Column 19, Line 8, delete "space, it" and insert -- space. It --, therefor.

In Column 19, Line 26, delete "having as" and insert -- having a --, therefor.

In Column 19, Line 55, delete "color image" and insert -- color. Image --, therefor.

In Column 19, Line 58, delete "(2>4" and insert -- (2x4 --, therefor.

In Column 19, Line 66, delete "sets. Where" and insert -- sets, where --, therefor.

In Column 20, Line 32, delete "5 hits," and insert -- 5 bits, --, therefor.

In Column 20, Line 38, delete "716; 722," and insert -- 716, 722, --, therefor.

In Column 21, Line 38, delete "first hit" and insert -- first bit --, therefor.

In Column 21, Line 46, delete "than 780" and insert -- diffbit 780 --, therefor.

In Column 21, Line 57, delete "the hits" and insert -- the bits --, therefor.

In Column 22, Line 1, delete "generate" and insert -- generate a --, therefor.

In Column 22, Line 5, delete "for more" and insert -- (or more --, therefor.

In Column 22, Line 13, delete "hits" and insert -- bits --, therefor.

In Column 24, Line 9, delete "or" and insert -- (or --, therefor.

In Column 24, Line 57, delete "$\text{Green: } 110_{bin} \leftrightarrow 2 \Rightarrow 214-2=212$" and insert -- $\text{Green: } 110_{\text{bin}} \leftrightarrow -2 \Rightarrow 214-2=212$ --, therefor.

In Column 25, Line 34, delete "the follow" and insert -- the following --, therefor.

In Column 25, Line 39, delete "the rod" and insert -- the red --, therefor.

In Column 25, Line 44, delete "716; 722," and insert -- 716, 722, --, therefor.

In Column 25, Line 55, delete "$\text{Green 1: } 0000_{bin} \Rightarrow 00000000_{bin}0$ " and insert -- $\text{Green 1: } 0000_{\text{bin}} \Rightarrow 00000000_{\text{bin}}=0$ --, therefor.

In Column 26, Line 6, delete "rest:" and insert -- rest --, therefor.

In Column 26, Line 10, delete "ming" and insert -- following --, therefor.

In Column 26, Line 17, delete "triode" and insert -- mode --, therefor.

In Column 26, Line 35, delete "one:" and insert -- one --, therefor.

In Column 26, Line 61, delete "716; 722," and insert -- 716, 722, --, therefor.

In Column 26, Line 62, delete "726; 732," and insert -- 726, 732, --, therefor.

In Column 26, Line 65, delete "$R_0\text{: } 011001_{bin} \Rightarrow 1100101_{bin}=101$," and insert -- $R_0\text{: } 011001_{\text{bin}} \Rightarrow 01100101_{\text{bin}}=101$ --, therefor.

In Column 27, Line 17, delete "(101, 6, 8)." and insert -- (101, 86, 8). --, therefor.

In Column 27, Line 29, delete "processing" and insert -- processing) --, therefor.

In Column 27, Line 43, delete "unit 1110" and insert -- unit 100 --, therefor.

In Column 28, Line 12, delete "according," and insert -- according --, therefor.

In Column 28, Line 22, delete "decoder 200" and insert -- decoder 220 --, therefor.

In Column 28, Line 65, delete "sin" and insert -- size --, therefor.

In Column 28, Line 66, delete "site" and insert -- size --, therefor.

In Column 29, Line 54, delete "thither" and insert -- further --, therefor.

In Column 30, Line 35, delete "index," and insert -- index --, therefor.

In Column 30, Line 51, delete "having," and insert -- having --, therefor.

In Column 30, Line 66, delete "applied," and insert -- applied --, therefor.

In Column 31, Line 34, delete "according," and insert -- according --, therefor.

In Column 31, Line 35, delete "as color" and insert -- a color --, therefor.

In the Claims

In Column 33, Line 58, in Claim 6, delete "based on at the" and insert -- based on the at --, therefor.

In Column 33, Line 64, in Claim 6, delete "block; and" and insert -- block; --, therefor.

In Column 34, Line 45, in Claim 12, delete "to a generate" and insert -- to generate --, therefor.

In Column 34, Line 60, in Claim 12, delete "block; and" and insert -- block; --, therefor.